3rd Australasian Engineering Heritage Conference

Engineering in the Development of a Region:

History and Heritage

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John Harry Grainger, Engineer and Architect.

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SUMMARY: *John Grainger, the father of internationally famous composer Percy Grainger, was as talented and gifted as his famous son but, unlike Percy, he is little known today. While John Grainger had a deep love of music, his talents were expressed in the many buildings, bridges and other engineering works that he designed. Despite being subjected to recurring bouts of debilitating illness, he designed fourteen bridges, at least five water supply and irrigations schemes and a large number of buildings, many of which are on heritage registers in both Australia and New Zealand.*

1. INTRODUCTION

John Harry Grainger was born in London on the 30th of November 1854 at 1 New Street, Westminster[1]. He was said to have spent his early childhood at Durham and then, at the age of 14, he went to a monastery school in France[2]. Grainger started his engineering training when he was fifteen in the office of W.E. Wilson MICE of Dean's Yard, Westminster and studied architecture under I.J. Eden & W.K. Green of Westminster. In the mid 1870s, while still in Wilson's employ, Grainger travelled throughout Europe, visiting Spain, Italy and France[3].

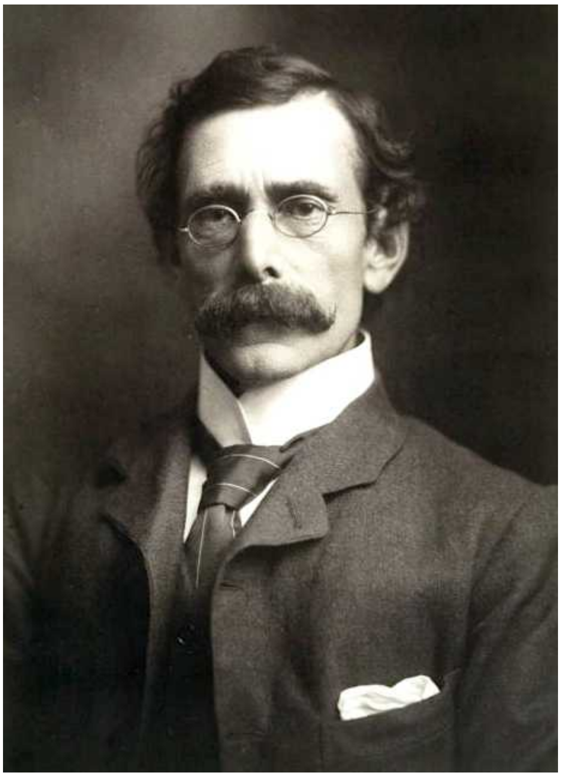

Figure 1. *John Grainger 1901*

2. EARLY YEARS IN SOUTH AUSTRALIA 1877-1880

John Grainger arrived in Adelaide aboard the *Tanjore* on 1 February 1877 to take up a position in the office of A.C. Mais, Engineer-in-Chief of the South Australian Public Works Department[4]. He resigned in July 1878 after he had won the competition for the Albert Street Bridge in Adelaide and was starting to get private work from a number of wealthy clients.

The Albert Bridge design by John Grainger and Henry Worsley was selected from several others in an open competition. In February 1878, the Davies and Wishart tender of £7,500 for construction of the bridge was accepted; the final cost of the bridge was £9,000. The foundation stone was laid on 20 August 1878 and the bridge opened on 6 May 1879. The bridge is listed on the South Australian Heritage Register.

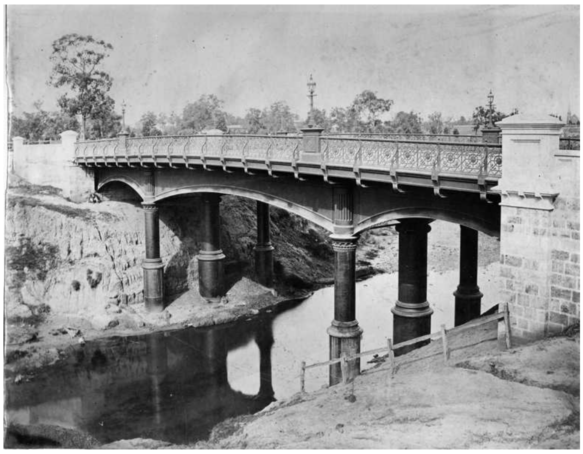

Figure 2. *Albert Bridge Adelaide*

The width of the bridge is 12.8 m between the handrails and the overall length is 36.6 m made up of three spans of 9.15 m, 18.3 m and 9.15 m. Each span has the appearance of being separately arched, but actually consists of three continuous 36.6 m long girders spaced 4.57m apart. The girders have their bottom flanges curved to give the appearance of three separate 'arches'. The 9.15 m side spans are cantilevers that are balanced by the 18.3 m central span. The piers therefore bear the whole weight of the bridge and relieve the abutments of any vertical reaction from the bridge. As a result, the abutment foundations are only 1.83 m below ground level. Resting on top of the main girders is a series of I-beams, at 1.83 m centres, that cantilever to support the 1.83 m wide footways. Originally graded jarrah timber joists spanned longitudinally over the I-beams to support 75 mm thick deck planking. In 1935 the timber deck, which had been affected by dry rot and termites, was replaced by a 240 mm thick reinforced concrete deck.

The ironwork for the beams was ordered from the Axeltree Co. in Wednesbury near Birmingham and shipped out to Adelaide where it was fabricated, and erected under the supervision of the City Surveyor J.E. Langdon.

The main girders are supported by three cast-iron piers near the edge of each bank of the River Torrens. The structural connections between the outer piers and the girders are concealed by semi-cylindrical classical mouldings, enhancing the appearance of the bridge.

The newspapers of the day, reporting on the laying of the foundation stone, the progress of construction and the opening of the bridge, named only Grainger as the designer of the bridge. Worsley is not mentioned.

The Albert Bridge is an early example of Grainger's aesthetic design sense and contrasts strongly with the utilitarian Hindmarsh Bridge, which had identical spans, cast-iron cylindrical piers and stone abutments and was erected one year later downstream from the Albert Bridge[5].

Figure 3. *Hindmarsh Bridge*

Shortly after the Albert Bridge was opened, Grainger won competitions for two Victorian bridges, the Sale Swing Bridge and Princes Bridge in Melbourne; with prize money of £50 and £200 respectively. Jenkins & Grainger were listed as the winners of the competition but it has been argued that Grainger was the sole designer[6] .

The need to create working drawings for the two bridges resulted in Grainger later moving to Melbourne.

While Grainger was working on these bridge designs, he also embarked on a social and musical life in Adelaide. He had a deep love and understanding of music, and was held in great respect throughout his life by his highly musical friends. Through musical gatherings, Grainger met wealthy Adelaide patrons such as Thomas Elder and Robert Barr Smith and many others in the network of the Barr Smith family.

His largest architectural commissions were for two houses for the wealthy Robert Barr Smith. One was **'**Auchendarroch**'** at Mt Barker, a very large and distinctive mansion described rather optimistically as being in the French Renaissance style. The other was for alterations to 'Torrens Park' at Mitcham to install Morris & Co. interiors and for the addition of a private theatre.

Another design with connections to the Barr Smith family was additions of the bluestone nave and tower for St Andrews Church at Walkerville, South Australia. These were impressive Gothic designs in which could be seen Grainger's dedication to direct and simple expression in architecture.

All three of these buildings are on the South Australian Heritage Register.

In February 1880, Grainger made his first visit to Victoria to inspect the site for the Sale Swing Bridge and to exhibit his design for the bridge at the Sale Council Chambers. He then started work on the final drawings for the bridge.

On the 1st of October 1880, he married Rosa (Rose) Annie Aldridge at St Mathew's Church, Kensington Road, Adelaide.

3 THE BOOM YEARS 1880-1888

Shortly after the marriage the Graingers moved to Melbourne to enable John to be closer to his two major projects, the Sale Swing Bridge and Princes Bridge. Their house was in New Street North Brighton and it was here that Percy Grainger was born on 8 July 1882.

In 1880 construction of the Sale Swing Bridge commenced and it was completed in 1883. Grainger travelled to Sale to supervise the construction. Before the bridge was first opened it was test loaded with 240 head of cattle.

The bridge is classified by the National Trust, and is on the Victorian Heritage Register (H1428). The statement of significance for the bridge says, in part, '*The Swing Bridge is architecturally significant as the only bridge*

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of its type in Victoria, with few others of this type and degree of sophistication elsewhere in Australia'.

The bridge has two end spans of 5.6 m and the central swing section of 45.7 m. The main girders are two wrought iron trusses connected transversely by riveted wrought iron cross girders. The swing section of the bridge is pivoted on a central circular rail and small rollers, supported on nine circular piers. A hand-operated mechanism allowed the bridge to be swung open so that river traffic could pass.

The castings for the turntable etc were fabricated by Messrs Johnson & Co. of Melbourne. The bridge contractor was Peter Platt, a councillor on the Sale Borough Council. The final cost of the bridge was £6,857.

At least eleven swing bridges were built in Australia in the late 19th and early 20th century, five of these still exist, with the Sale Swing Bridge being the oldest intact swing bridge left in Australia. VicRoads recently restored the bridge at the cost of $1,200,000. During summer and autumn, it is opened twice a week and has become a significant tourist attraction for Sale.

Percy Grainger crossed the Swing Bridge when the Ada Crossley concert tour visited Sale in 1903 and 1908. On the first occasion, the mayor arranged a ceremonial opening of the bridge.

Figure 4. *The Restored Sale Swing Bridge*

John Grainger was officially engaged on 10 March 1881 by the Victorian Public Works Department (PWD) to prepare plans for Princes Bridge. By November of that year, the plans and specifications had been completed and forwarded to the Melbourne City Council for approval. During 1882, a series of delays occurred because alterations were made to the siting of the bridge and the revised drawings were not completed until the end of that year. Before construction of the bridge took place, further changes, including strengthening the bridge to take cable trams were required. Grainger was not employed to undertake these amendments; instead, they were done by F. M. Hynes, a civil engineer in the PWD.

The contract for construction of the bridge was not signed until 16 November 1885, over six years after it was announced that John Grainger had won the original competition. Grainger made several requests to supervise the construction but these were denied.

The successful tenderer for the bridge was David Munro with his quotation of £137,000.

The final form of the bridge did not differ greatly from Grainger's original design consisting of three arched spans of 30.5 m, a straight span of 7.3 m on the south side and a larger straight span at the other end to accommodate trains. The width of the bridge is 30.2 m, which accommodates two 5.5 m wide footpaths, four lanes of traffic, and two tram lines down the centre. The waterway was widened from 40m to 96 m to overcome flooding problems that had been previously experienced.

Each arched span is made up of ten curved wrought iron riveted plate girders braced by six cross bracing trusses. Riveted to the top of each curved girder are triangular lattice trusses, which create a horizontal plane to support secondary riveted wrought iron beams at 1.61m centres, these in turn support buckle plates, concrete and then initially a wearing surface of timber blocks. The bluestone abutments and piers are founded directly on Quaternary basalt. The piers are parallel to the flow of the Yarra River and consequently are set at an angle of 75 degrees to the roadway.

The young John Monash gained his first engineering experience working on the bridge for the contractor David Munro, who was also building two other bridges over the Yarra at the same time, the Sandridge Railway Bridge, opened in 1888 and Queens Bridge opened in 1890.

Princes Bridge was finally opened on 4 October 1888. Despite the changes that occurred from the original prize winning design, it is a prince among bridges in Australia and is rightly prized and protected (Heritage Register, H1447).

Figure 5. *Princes Bridge Winning Design Entry*

Figure 6. *Princes Bridge Today*

Shortly after Grainger was appointed to prepare the drawings for Princes Bridge he went into partnership with Charles D'Ebro, another architect and engineer who had come out to South Australia on the same ship as Grainger and who had also worked in the Engineer-in-Chief's Department in Adelaide.[7]

The partnership was extremely successful in the four years that it existed. In 1882, Grainger & D'Ebro were engaged to design and arrange the installation of a reticulated water supply for Benalla and they called tenders on behalf of the Shepparton Water Trust for a weir across the Broken River, floodgates, bridges and the cutting of a water channel 2 miles 60 chains long. In the same year they designed the Fremantle Town Hall and the National Bank in Fremantle, won a competition for a new Presbyterian Church at St Kilda and the competition for a New Masonic hall in Melbourne.

Other competitions they won included the Auckland City's Free Public Library and Municipal Offices, the Grace Park housing development in Hawthorn, the South Brisbane Drainage Scheme and the Brisbane Public Offices (now known as the Queensland Government's Treasury Building). Their winning design for this building was not built as it was supplanted by a design of J.J. Clarke, the colonial architect for Queensland. They won a second prize for their Flinders Street Station Design and exhibited three designs for the Falls Bridge over the Yarra. Early in the partnership, they designed the Christ Church Congregational Church in Launceston, Tasmania (constructed 1883-85), which is also heritage listed.

The Georges Building in Collins Street is a well-known work from the early Melbourne years of Grainger & D'Ebro, though now much altered. Internally, the simple iron structure is clearly visible. Externally, each floor is defined by a continuous entablature and each floor is subtly different from the floor above or below, with an independent classical pediment surmounting the whole composition. It was described as Italian Renaissance in style and admired for what was described as Grainger's love of simplicity, the design being judged free from 'superfluous ornamentation' and 'excessive decoration'[8]. It was originally built as the Equitable Co-Operative Society Premises by David Mitchell, father of Nellie Melba and a family friend of the Graingers.

Figure 7. *Georges Building 162 Collins Street*

The Masonic Hall (completed 1886) was a particularly striking design with a central two-storey arcade flanked on either side by pavilion ends capped with towers. All the details were an evocation of English Palladian architecture seen through a late-19th century picturesque lens. It was a powerful presence on the south side of what was called the 'Paris' end of Collins Street, before it was demolished and Collins Place erected in its place.

Figure 8. *Masonic Hall Collins Street*

On 4 October 1883 another Grainger & D'Ebro designed building, the Servants Training Institute in Yarra Park near Bridge Road, Richmond was opened.

The firm also designed a number of houses and made additions to others. Some of the clients were family friends from the Brighton area.

On 14 April 1885 the partnership of Grainger & D'Ebro architect and engineers was dissolved. The reason for this is unknown. Grainger's increasing alcoholism may have been one reason and another his erratic behaviour and short temper. According to a recollection by Percy, '*he was quick to take offence when contradicted*'.

John Grainger then practised on his own from offices at 29 Queen Street Melbourne. In 1885, he called tenders for rebuilding the Kensington Maizena Works, a 2-storey villa in Brighton, additions to a villa in Hawthorn Grove, Burwood and he also entered the competition for the Bairnsdale Water Supply.

1886 saw him calling tenders for work at the Metropolitan Company's Brewery in Latrobe Street, West Melbourne, for alterations to the City Club Hotel in Collins Street and for three 2-storey villas in Darling Street, South Yarra. In addition, he was awarded the prize for the Bairnsdale Water Supply. On 10 November 1886, Grainger was awarded first prize for his design for the Maryborough School of Arts, Queensland beating thirty other entrants with his superb and distinctive classical design. This building is on the Queensland Heritage Register.

Construction of the Bairnsdale Water Supply Scheme started in 1887 and it was completed by early 1888. Several problems soon became apparent. The boilers had been placed on top of a hill with a 76 m naked steam pipe leading to the pumps at the river. This caused a loss of one-third of the steam pressure, necessitating the boilers being moved down to the riverbank next to the pumps. There were also problems with the pumps being subjected to flooding when the Mitchell River rose. The intake pipes were close to the tidal reach of the river and at times of low river flow and high tides the water could get salty, requiring first a suction box and later a weir to be built to overcome this problem. The Bairnsdale Pumping Station has a heritage listing (VHR H2040)

In February 1887, '*Mr. J. H. Grainger Consulting Engineer'* was appointed to do the detailed planning for a water supply scheme for Sale, with the water to be drawn from the Thompson River. The water tower for the scheme, consisting of a 13 m high cylindrical brick structure supporting a 40,000 gallon riveted iron tank, is still in use. The engines and pumps were started for the first time on Saturday 17 March 1888 and in April, Grainger inspected the works and gave his seal of approval[9].

Tenders for a large brick villa in Orrong Street East St Kilda were also called in 1887. The *Australasian Builder and Contractor's News* noted on 17 September 1887 that construction was to start for the Grainger designed Palace Hotel & Public Hall in Bourke Street.

The Robur Tea Building at 28 Clarendon Street Southbank, Melbourne, originally designed for the Fergusson & Mitchell Stationery Company, was constructed between 1887-88. The six-storey red brick building, which Grainger worked on as engineer with the prolific architect Nahum Barnet, was not only admired for its simplicity of expression, but also for Grainger's engineering skill in designing a tall building founded on the very weak Coode Island silt found at this location. Some 450 ironbark piles and a concrete raft support the superstructure. The effectiveness of the foundation system can still be seen today as there are no cracks in the external walls at any of the window and door openings. Another innovation was the use of steel beams to support the floors, one of the earliest uses of such technology in Victoria. This is one of the very few of Grainger's buildings from the 1880's that has not been demolished as the city has been redeveloped, hopefully the building will remain intact as it is heritage listed (H0526).

Between 1880 and 1890, John Grainger won, in open competitions, prize money to the value of £2,350.

4 THE LEAN YEARS 1888-1896

In 1882, while living in Brighton, John Grainger formed a platonic friendship with thirteen year old Amy Black that lasted until she was about thirty. Many letters written in the 1890s from Grainger to her survive. It is largely from these letters and those that he wrote to his father, Rose and Percy, all of which are lodged in the Grainger Museum at the University of Melbourne, that details of Grainger's life between 1888-1905 are known.

Around 1888, because of his heavy drinking, he began to experience severe attacks of delirium tremens, complicated by nicotine poisoning from smoking large numbers of cigarettes a day.[10]

At the beginning of 1890, Grainger wrote to his father '*Of course you know I lost all in over speculation in mines and afterwards in trying to make it up I overdid it in hard work. This at last nearly finished me off altogether. I am doing a lot of work now but most go to pay off mining and other speculations. …Working as a manager for another architect at 8 guineas a week-will go into partnership when cleared debts*.'

In the years 1888 & 1889 tenders were called in the name of Grainger and Naish, for repairs to the Morphettville racecourse, erection of a lodge room to a hotel in Mitcham, erection of a brewery in Broken Hill and a flourmill at Port Adelaide. Naish may have been the architect that Grainger referred to in his letter to his father.[11]

In 1890 Pitt and Grainger were awarded 2nd prize in a competition for a bridge over the Yarra at Spencer Street, Melbourne

Early in September 1890 Grainger left Melbourne for England to see his father, and hoping that the sea voyage would restore his health. He wrote to Amy Black from England that he had suffered '*such a fall as few men can scarcely hope to recover from… and that he was disturbed in mind and body'*. His father refused to see him and he returned on the same ship that had taken him to England, the *S.S. Oruba,* arriving in Adelaide on 18 December of the same year. From this time onwards John and Rose did not live together although occasionally Rose and Percy would visit John in South Australia until, in May 1895, they left Melbourne for Frankfurt to further Percy's career as a pianist.

In March 1891, he wrote to Amy Black that he '*had no money left to lose…how on earth am I to get 4d to post this letter*' and refers to a stay in hospital. In a later letter, he wrote that 'he had met Langley in about 1891 '*at that time I used to drink so badly'*. Langley asked him to give him a hand with plans for a cement works[12] and he agreed to do this for £3 a week '*as much as anything to get away from the detestable drink*.'

Grainger, in 1892, was awarded second and third prize in the Hamley Bridge (South Australia) competition.

In 1893, Grainger was working for £3 a week and his board for the wealthy pastoralist J. H. Angus at the Hill River cattle and sheep station near Clare in South Australia, designing and remodelling the buildings on the station[13]. This enabled him to send £2 a week to '*the dear little woman'*. In a letter to Amy Black, from the Hill River Station, he wrote '*Of course you know I have got the best of my big Enemy long since & don't touch whisky by any pretence now*.' In December, Grainger was back in Adelaide and wrote that '*I have some big alterations to date a house here (Hon. G. C. Hawker's), as well as a small lifting bridge and some extraordinary plans to make of the Coolgardie and Murchison Goldfields'*.

A year later he was writing from Mt Remarkable Station, 250 km from Adelaide, that he was engaged in putting some buildings in order, building new water tanks and laying out a big scheme of irrigation for the estate.

Langley wrote to Grainger in 1894 saying that he had an idea for a patent crushing mill and asked for his help in drawing it up[14]. According to Grainger '*In a few days I had designed the patented machine of which I was to receive 1/10th interest, which up to this time I have not seen although he sold the patent for £8,000*.'

On the 24 April 1895 he wrote on the letterhead of the South Australian Portland Cement Company that he had been in Adelaide since March and that he was getting out a scheme of machinery, plant and housing for the Company.

On 13 September 1895 Grainger met Winifred Falconer in Adelaide. She was to remain with him for the rest of his life. Though she became his lifelong friend, their relationship was always described publicly by the family in the most delicate way, with Rose referring to her as his '*nurse*' and he as his '*niece*'. Perhaps Winifred Falconer straightened him out and got him back into regular professional employment.

In a letter to Amy Black dated 12 December 1896, on the letterhead of Haycrafts G.R.&M. Co. Ltd., Kalgoorlie, Western Australia, he wrote *'Some few months ago in January, February 1896 I prepared a set of plans and specifications for Mining Plant using Langley's Patent Crushing Mill and Haycrafts Gold Reduction process. They offered me £6 a week, here I am, having left Adelaide last October 14th getting here 20th, that is Kalgoorlie. …In the first place I was until last July, doing very well in Adelaide but business fell off again as the share slump spoilt all business. I lost £800 I had made in speculation in shares in no time… Living with George Aldridge (*Rose's father*) in Adelaide since February 1895 until I came here'.*

On 29 December 1896, Langley dismissed Grainger and he sued for wrongful dismissal and his 1/10th share of the proceeds from the patent crushing mill.

5. PROFESSIONAL REVIVAL 1897-1905

After his dismissal Grainger went to Perth, he had splendid letters of introduction to Government Ministers in Perth, and on 1 March 1897, he was appointed Principal Architect in the Architectural Division of the Public Works Department at a salary of £600. On 16 January, just as his appointment was settled he became ill, possibly from typhoid, and returned to Adelaide where he went into a private hospital.

After the discovery of gold at Coolgardie in 1892 and then at Kalgoorlie in 1893 the population of Western Australia almost quadrupled between 1890 to 1900. New settlements on the goldfields increased the need for buildings to accommodate the growing number of civil servants required for administration of the leases and collection of fees, to maintain law and order and provide communications, education and hospital services. The Government's expenditure on buildings rose sharply to a peak of £448,000 in 1897-98[15], the year Grainger joined the PWD. To meet this demand standardised buildings were designed and used where possible but for the larger and more important buildings, this was not possible and Grainger's design skills were needed for these.

His designs included the Romanesque flavoured Government House Ballroom, which was greatly admired by everyone, and impressed the twenty-two year old Percy Grainger when he saw it in 1904. Other buildings linked to Grainger's name include the Supreme Court, the Perth Art Gallery (suggestive of American Romanesque), Parliament House, Perth Central Police Courts and a number of substantial goldfields buildings. These included the powerful Warden's Court in Coolgardie, where Grainger changed and enlarged the design by his predecessor G. Temple Poole and the equally powerful Public Buildings in Kalgoorlie. There were also many smaller government buildings in country areas. Many of the above mentioned buildings are registered by the Heritage Council of Western Australia, as are several Government buildings in Boulder and other towns that were designed by Grainger.

Figure 9. *Government House Ballroom, Perth.*

While designing and preparing all the drawings for the Government House Ballroom his health deteriorated and in August 1897 he went back to Adelaide for a month. He returned and wrote that '*All our men have been busy, engaged on Standard Drawings, a new Lunatic Asylum, Art Gallery and several important buildings'*.

In a letter to Percy in July 1898, Grainger wrote '*The Royal Mint I expect to open in a month, new Public Library about the same date, Coolgardie and Geraldton Public Buildings ditto, Albany Quarantine Station has been completed.'*

Figure 10. *Wardens Court Coolgardie*

By the end of 1898, he is writing to Percy that '*work is very slow but that Law Courts and Parliament House are going on'*. At the beginning of 1899, Grainger had to dispose of all of his draftsmen and his chief clerk and was unsure of his own position. The slow down in work may well have been because the Western Australian Government was spending all its revenue and loan monies on the Coolgardie Goldfields Water Supply Scheme, which entailed building a 560 km pipeline and associated pump stations from a dam near Perth to Coolgardie and then to Kalgoorlie.

During this slow period, Grainger undertook a private commission for what he called 'the Colombo Building' but which the owner, Mr Davies, intended to call the Australia Building in Colombo. It appears from his comments that he prepared a set of drawings and then had draftsmen make copies. He also wrote the specification and made a sheet of details for the ironwork, giving all the lengths and numbers of iron joists so that the owner could write to the supplier and order them as required, (presumably using his engineering skills to design the beams and columns, etc).

In September 1899, Grainger was given a significant government commission that brought him to the attention of the press in England. This was to design the Western Australian Court for the Great Paris International Exposition of 1900, which Grainger attended to supervise the erection of the exhibits. These included a big mining display and an impressive display of local timbers. His design of the court led to him being awarded a medal by the Société Centrale des Architects Française. This was the only professional body that Grainger belonged to during his career.

During this trip, he briefly visited Rose and Percy in London.

Back in Perth in 1901, he provided the designs for the street arches erected for the Royal visit of the Duke and Duchess of Cornwall and York.

In 1903, his department completed drawings for the Perth Central Police Court, the Perth Central Police Station, the Commissioner's Office and Men's

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Barracks, Fremantle Gaol additions and the new wing for the Perth Government Offices. Work was in progress on the new Parliament House, the Perth Supreme Court building was completed and contracts were let for the Claremont Hospital for the Insane and the Perth Victoria Public Library. By 1903 Grainger's salary had been increased to £1,000 per annum,

Figure 11. *Perth Victoria Public Library*

In November 1903, John Grainger was suffering increasingly from 'r*heumatic*' pain and he took three months leave. He sailed to New Zealand for treatment at the hot springs at Rotorua, accompanied by his '*nurse*' Winifred Falconer. When Percy, then on a concert tour, met him in New Zealand, he described him as '*the totalest (sic) wreck I have ever seen.'*

The Architectural Division still had a heavy workload in 1904, with work being completed on 199 contracts at a cost of £110,000 for buildings that varied from courthouses to quarantine stations. The annual report for the Division was signed by Hillson Beasley, Acting Chief Architect, at the end of which he wrote '*The unfortunate illness of the Chief Architect and his consequent absence from duty for several months has imposed extra responsibility and work on the staff generally'*.

In the Parliamentary Report for 1905, Grainger's salary is listed as £1,000 with a note that he retired 31/7/1905 '*on completion of the term of agreement'*. Hillson Beasley then became Chief Architect on a salary of £500. The disparity between the salaries is an indication of how much Grainger's architectural skills were valued by the Public Works Department.

During his years in Perth, John Grainger continued to send money to help support his wife and son in London, as he had earlier done when they were in Germany, a situation that was later to be dramatically reversed.

When he retired from the PWD his health was again bad with his '*hands terribly sore'* from what he called rheumatism and with Winifred Falconer he left Australia to seek a cure for his ailments in the sulphurous baths at Harrogate, England. Late in the year, the couple left England for Europe travelling in Spain, Italy, Sicily, France and Belgium.

6. FINAL YEARS OF PRACTICE AND ILL-HEALTH

With John Grainger's health improved, he and Winifred sailed from London in June 1906 and returned to Melbourne where Grainger re-established himself in architectural practice.

According to Winifred Falconer, Grainger arrived in Melbourne '*in time to enter his design for a competition for the Administrative Block of the Melbourne Town Hall & altho hampered by a right hand crippled with neuritis, he made all the huge drawings unaided, his design securing First Prize'*.

In September 1906 Grainger applied to become a Fellow of the Royal Victorian Institute of Architects (RVIA). His nomination was proposed by Percy Oakden and seconded by Francis John Smart and John Little, all Fellows of the RVIA and prominent architects. His submission listed many of the projects he had designed in Adelaide, Melbourne and Perth and the awarding of a special medal by the Architects Françaises for his work on the Western Australian exhibits at the Paris International Exposition. Despite this impressive curriculum vitae, when a ballot was taken at a general meeting of the RVIA on 23 October 1906 the members in attendance voted not to elect him as a Fellow. Between 1906 and 1910, he was the only candidate not elected. The President of the RVIA and chairman of the meeting was Charles A. D'Ebro, Grainger's partner from the 1880's. Whether this had anything to do with his failure to be elected is not known[16].

He was taken into a partnership styled Grainger, Kennedy & Little, which later became Grainger & Little and then Grainger, Little & Barlow. After Grainger died, his name was still being used by the firm up until at least 1924.

With somewhat renewed vitality, he was involved in the design of St Michaels Church, North Melbourne and the interior of Town Hall Administration Offices. J.J. Clarke, who had supplanted Grainger for the Brisbane Public Offices and who had come second in the competition for the Town Hall Administration Offices, again supplanted Grainger being engaged to design the exterior of the building.[17] Clarke's design is largely a pastiche of Reed & Barnes 1867-70 Town Hall exterior.

The various partnerships had influential and wealthy clients and designed several large and impressive buildings now demolished: Collins House in Collins Street, the State Savings Bank on the corner of Bourke and Elizabeth Streets, and the remodelling of Cliveden

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Mansions. Grainger also designed Dame Nellie Melba's Music Room for her house in Coldstream.

Grainger & Little were at the forefront in the use of reinforced concrete, in association with John Monash's firm the Reinforced Concrete and Monier Pipe Construction Company (RCMPC). Reinforced concrete was used in the Town Hall Administrative Offices, the State Savings Bank, Collins House and for the Gippsland Factories Co-operative Produce Company's building in Flinders Lane. In 1910, when Monash was overseas, Fairway, who was in charge of the company during his absence, wrote to Monash that '*the architect John Grainger was now involved in the project (Collins House) and was insisting that he would have reinforced concrete in the building only if it were done by a reputable firm-and that he wanted RCMPC.'*

In 1909, the Victorian Government appointed Grainger, described as a leading architect of wide experience, to make a full inquiry into the Architectural Branch of the Public Works Department. His recommendations were adopted, favouring the standardisation of plans, specifications, and details to overcome unpredictable variety and costs, and with the Department being placed under the firm control of a Chief Architect.

It is difficult to judge how active a professional role Grainger was able to play in these years in Melbourne because of his declining health and because he again travelled to England, arriving on 29 March 1912. He was accompanied by his faithful companion Winifred Falconer, described on this visit as his '*niece*'. John Grainger's final decline extended over a number of years. He claimed this began in August 1914 when he was stressed in finishing drawings for Elizabeth House for the National Bank at the corner of Elizabeth and Little Collins Streets (now demolished). By the end of 1915, '*rheumatism*' had taken over the whole of his body.

By 1916 he could no longer write and was having to dictate his letters to Rose and Percy thanking them for the £12 a month they were sending and noting that the £6 per week his old firm was giving him as a living allowance would end in July.

During these last years of great pain, Winifred Falconer nursed him until his death on 13 April 1917 at the age of 62. Grainger died leaving only £267-12-7, and was buried in Box Hill Cemetery. His death certificate states that he died of chronic rheumatic arthritis - one of the handful of medical euphemisms commonly used in those days to cover the effects of tertiary syphilis. [18]

7. CONCLUSIONS

Tragic as the ending of each of the periods of John Grainger's professional life may seem, they cannot obscure his high artistic and professional skill in architecture and engineering, nor diminish the admiration his contemporaries had of him as an architect, an engineer and a refined musical amateur. Between his late twenties and early forties, he was at the height of his profession with designs built in every state in Australia and in New Zealand. His greatly admired Ballroom at Government House in Perth and Princes Bridge in Melbourne stand as symbols of his age and a bright flash of high architectural and engineering talent between deepening troughs of ill health.

8. ACKNOWLEDGMENTS

- George Tibbits. This paper is an expanded version of a paper that George wrote in 2008 for the Guest Speaker Series for Engineering Heritage Victoria. Regrettably, shortly after that paper was given, George died.
- Figure 1, Bartletto Perth, *John Grainger ,1901* gelatin silver printing-out paper mould on board; 206 x 14 cm Grainger Museum Collection, University of Melbourne.
- Figure 2 & 3 images courtesy of the State Library of South Australia. SLSA: PRG 280/1/28/145 Albert Bridge. SLSA B 43193 Hindmarsh Bridge.
- Figure 5 A. C. Cooke engraver after Jenkins and Grainger "The prize design for the new Prince's Bridge", in the *Illustrated Australian News*, 30 August 1879 p. 136.
  Figure 7 *Harold H. Paynting. Commercial Photographic Company.* Whereas the men's outfitters were at one end of Collins Street, the ladies were catered for at "Georges" in the centre of town.
  Figure 8 Charles Rudd H3957/87 dated 1886/7 'Masonic Hall, Collins Street east', c. 1887 designed by Grainger & D'Ebro, photograph on gelatin silver printing out paper
  Images courtesy of the State Library of Victoria, Pictures Collection.
- Astrid Britt Krautschneider, Curator, Collections and Research, Grainger Museum for access to the documents on John Grainger's life.
- Miles Lewis for his invaluable *Australian Architectural Index* that enabled the identification of the many buildings Grainger designed.

9. REFERENCES

(see next page)

[1] This date and place of birth are from Grainger's birth certificate. John Bird, 1977, *Percy Grainger,* p 3, MacMillan Co. South Melbourne, has John Grainger being born on a train coming into a London Station on 30 November 1855.

[2] Winifred Falconer 1934 *The Life and Works of John Grainger, Architect and Civil Engineer*, the manuscript is held in the Grainger Museum, University of Melbourne. Whether this is correct is open to doubt as his parents were still listed as living in Westminster at the time of the 1881 census.

[3] Grainger's application for RVIA Fellowship, dated 17 Sept 1906, RVIA Papers Australian Manuscript Collection, State Library of Victoria.

[4] There is no record of a John H. Grainger being employed by the South Australian Public Service in the years 1877-1879. Provisional and temporary staff were not listed by name in the annual reports of the South Australian PWD. There were two clerks of works listed as provisional or temporary staff in the Architectural branch of the PWD and whether Grainger occupied one of these positions could not be ascertained.

[5] Aesthetics came at a cost; the tender for the Hindmarsh Bridge was £1,500 less than that for the Albert Street Bridge, partly because the straight beams could be fabricated in South Australia.

[6] Allom Lovell & Associates, 2002, *Princes Bridge, Swanston Street, Conservation Management Plan* p 12. See also Susan Reidy, 2007, 'Prince's Bridge and John Grainger', *John Harry Grainger Architect and Civil Engineer* p 20-21. University of Melbourne

[7] *Australian Engineering and Building News* 1.6.1881, p 236.

[8] *Argus* 15 August 1883, p 3.

[9] Peter Synan, 1988, *Precious Water 1888-1988,* City of Sale.

[10] John Bird, 1977, *Percy Grainger,* p 14, MacMillan Co. South Melbourne,

[11] Francis John Naish had been employed as a draftsman in the South Australian PWD in 1878 when Grainger was said to have been working there, he later had his own practice in Adelaide.

[12] Richard Durrant Langley was associated with various cement works in Australia including the South Australian Portland Cement Co. Ltd. In December 1892, the cement works that Langley was building for the Company was completed.

[13] J.H. Angus loaned money to the South Australian Portland Cement Company to enable it to complete the construction of the cement works and may well have met Grainger at this time.

[14] Langley applied for a patent on the 29th of November 1894 for "An improved rotary grinding and pulverizing machine", *Victorian Government Gazette No 7* Monday January 21,1895, p 224

[15] Duncan Richards, 1994, *Creating the Public Realm, Public Architecture in Western Australia: 1890-2000* p 13, Perth W.A.; The Service and the Authority

[16] The RVIA were upset that they were asked only to ascertain whether the entrants for the Town Hall competition had complied with the conditions of the competition rather than to help judge it.

[17] This was despite a RVIA deputation telling the Melbourne City Council that the architects whose design had been awarded 1st prize were the only architects who could satisfactorily carry out their own design.

[18] John Bird, 1977, *Percy Grainger,* p 158, MacMillan Co. South Melbourne.

3rd Australasian Engineering Heritage Conference 2009

Port Craig Viaducts Engineering Assessment and Conservation Plan

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SUMMARY: *The Port Craig viaducts in Southland, New Zealand are located over deep gullies on the bush tramway that operated from 1917 to 1930 as part of the Port Craig timber harvesting and milling operation. This was the first introduction of high production heavy hauler harvesting in New Zealand and forms a notable chapter in indigenous logging history. The largest of the four timber viaducts, the Percy Burn, is 125m long and 36m high and was built to carry an 80 tonne hauler and also the passage of loaded log trams. These viaducts are the four largest remaining timber bush tramway viaducts in New Zealand and they remain fairly intact. These viaducts are now important visitor attractions and heritage items, but time and the elements have contributed to their deterioration since the mill closure in 1930 to the point where, without remedial work and preservation, they will begin to collapse. The history and significance of the Port Craig sawmilling story is covered in a paper in these proceedings titled* ***"Heritage Management at the Port Craig Sawmill Complex: Successes and Challenges"*** *by Rachael E Egerton, Department of Conservation.*

In 2007 The Port Craig Viaducts Charitable Trust commissioned a conservation plan for the purpose of documenting the history and significance of the viaducts as well as carrying out a detailed engineering assessment and developing a plan for their future restoration. This paper describes viaducts, as well as the methodology used to inspect and assess the viaducts and to develop the conservation plan and recommended restoration work. The conservation plan completed in August 2008 was prepared jointly by Chris Cochran, Conservation Architect; Michael Kelly, Heritage Consultant; Russell Murray, Conservation Architect and Trevor Butler, Consultant Engineer.

1. BACKGROUND

The Port Craig Viaducts were built as part of a bold initiative in 1917 by the Marlborough Timber Company to introduce large scale North American hauler logging techniques to New Zealand. The Southland coastal forest to the west of Port Craig offered the extensive harvestable terrain and was believed to contain the high volumes of timber to justify this scale of operation, previously unseen in New Zealand.

The several haulers for this operation were heavy pieces of equipment, the largest being the Lidgerwood hauler with a weight of 80 tonnes. The movement of such equipment required a substantial tramline with gentle grades so that it could be shifted to each setting location and set up for log hauling. Because the haulers were capable of high production rates, a reliable and efficient bush tramline was necessary to transport the logs from each hauler site to the mill at Port Craig. The tramline was built to 3' 6'' gauge (the New Zealand Railways' standard) rather than the narrow gauge typical of bush tramways. Hence, the curves had to be constructed with a much larger radius and the cuttings excavated wider than had been previously typical on bush tramways.

The tramway route traversed a wide relatively easy sloping terrace between the coastal escarpment and the steeply rising Hump Ridge to the north. The biggest impediments to the tramway were the incisions of four rivers, which have cut deeply into the terrace. To bench-cut the tramline into these deep ravines to cross the streams at a low level would have required significant additional length of tramline and the grades and curves required would have inhibited the efficiency of the logging operation. The solution was to construct large elevated timber trestle viaducts across these ravines. The first of these, near Sand Hill Point is only seven kilometers from the Port Craig Mill site, and the largest viaduct of the four, the Percy Burn is located only 800 metres beyond the first. These are believed to have been constructed in 1925.

Figure 1. *Lidgerwood chassis on the interpretative walk at Port Craig. (Crown Copyright: Department of Conservation, Te Papa Atawhai, 2005, Photographer: Rachael Egerton.)*

2. VIADUCT DESCRIPTION

Each of the viaducts is a large structure. The dimensions are shown in Table 1

Table 1 : Port Craig Viaduct Dimensions	
Sand Hill Viaduct	
Length	59m
Height	17m
Percy Burn Viaduct	
Length	125.2m
Height	36m
Edwin Burn Viaduct	
Length	50m
Height	22m
Francis Burn Viaduct	
Length	51.5m
Height	14.6m

Relatively little is known of the exact sequence the viaducts were constructed and the actual method of construction. Original drawings have not been found, however much of the detailing is typical of the type of construction found on many similar railway viaducts in New Zealand, Australia, USA and Canada. At one stage it was believed that the Percy Burn viaduct was one of the largest remaining timber trestle viaducts, however research by Michael Kelly has revealed several in existence that are higher and longer. Possibly the largest is the Goat Canyon Trestle in California, built in 1933 and standing a staggering 56m high and having a length of 197m.

Consistent with the high load capacity requirement and the expectation by MTC that the viaducts would provide access to the district after logging ceased, Australian hardwood timber was imported for their construction due to its greater strength and durability in comparison with New Zealand native timbers. Bolts for the bolted connections were made at Port Craig.

All four viaducts exhibit similar design features, but each has its own peculiarities, suggesting that there was some refinement of the design, and also adaptation to meet the specific challenges that each site presented. The towers of the Sand Hill viaduct are constructed from round hardwood poles with the low durability sapwood left in place. The latter viaducts are all constructed from squared timbers with the sapwood removed.

Figure 2. *Current appearance of Percy Burn Viaduct*

The towers of the Percy Burn and Edwin Burn viaducts have splices in the main columns because it was not possible to source and transport a single length of hardwood to match the full height of these viaducts. The highest columns of the Percy Burn viaduct required three separate timber columns spliced end to end to achieve the necessary 36m height. The Edwin Burn viaduct has a longer central span with steel tie bars so that the wider main stream channel could be crossed without the need for a pier within the waterway.

Figure 3. *The longer central span of the Edwin Burn Viaduct*

The footings of the piers near the base of the ravines consist of concrete pads founded on the mudstone rock. The piers nearer the ends of the viaducts consist of the hardwood columns being simply embedded into the clay gravel soil.

The rail deck of each viaduct was typically supported by large cross section timber beams spanning an average of 10m between corbels at the piers and propped with pairs of diagonal props from each pier. This structural form is very efficient on materials. Diagonal bracing to the piers is provided by railway irons and longitudinal stability to the piers is provided by horizontal timber members running the full length of the viaducts and anchored to the ground at each end. It is these horizontal braces that exhibit possibly the only serious deficiency in original design. The half splices at the ends of these bracing members have suffered from severe decay and many of these braces have fallen from the viaducts.

3. HISTORY

The viaducts were in use for little more than five years. The Port Craig sawmilling operation was closed in 1928 as a result of forest yields being well below that expected, and the high capital cost of the logging operation being well beyond that which could be economically sustained. It re-opened briefly in 1930 before closing permanently.

The tramway and viaducts deteriorated and in 1937, the successor of MTC, Holdings Ltd salvaged the rails and other items of value, but left the viaducts in place. For the following decades the viaducts provided access for hunters and trampers however by the 1970's the decks, made from locally sourced timber of low durability, had deteriorated such that any crossing of the viaducts on foot was somewhat precarious. The NZ Forest Service undertook basic repairs and in 1979 the Deerstalkers Association re-decked the viaducts.

By the 1990's there was growing recognition that the Port Craig Viaducts had heritage value and that there was merit in undertaking work to prolong their existence. Detailed drawings were prepared in 1987 and public meetings held to engage community support for remedial work on the viaducts.

In 1993, Southland's Port Craig Viaducts Charitable Trust was formed with the aim to stabilise the viaducts. With extensive voluntary community support, and the input of a rigging contractor, extensive work was carried out on the Percy Burn Viaduct in 1994 which involved replacement of rotted timbers with bolted splices, and the application of preservative treatment.

The other three viaducts received remedial work in 1999 consisting of replacement of critical bolts, rails and timbers. Further work on the Percy Burn Viaduct was carried out at this time as well.

Three of the viaducts lie on legal road reserve and are owned by the Southland District Council. The Edwin Burn viaduct is on freehold Maori land. Management of the viaducts is vested with the Port Craig Viaducts Charitable Trust, with the support of the Southland District Council (SDC), Venture Southland, DOC, and NZHPT.

In 2007 the Trust commissioned a detailed conservation plan for the four viaducts and engaged Chris Cochran (Conservation Architect), Trevor Butler (Engineer), Michael Kelly (Heritage Consultant) and Russell Murray (Conservation Architect) to prepare the plan.

4. ENGINEERING INVESTIGATIONS

The methodology for assessment of the viaducts consisted of:

- Review of previous inspection and upgrade reports
- Detailed visual assessment from ground and deck level
- Assessment of condition of each component member based on visual appearance, close inspection and sounding with a hammer.
- Abseil inspection of selected locations.
- Review of deck lateral load deflection data.
- Detailed photographic record.

Figure 4. *Close inspection of Percy Burn Viaduct piers*

3

Whilst there was a significant body of knowledge about the condition of the viaducts from several previous inspections and reports, it was clear that for the purpose of the Conservation Plan it was necessary to establish a schedule of the condition of each component for each viaduct.

This schedule was prepared over a period of 8 days on site with the assistance of Trust personnel and rope access experts from Adventure Southland. It involved establishment of a clear component identification system and then for each component, recording its physical dimensions, materials and condition. For timber members this included recording the percentage of length that was affected by rot and also the extent of replacement by splicing in new timber that had taken place in the past.

This detailed investigation was carried out by visual assessment from deck level and ground level using binoculars, and was followed up by representative test boring and close inspection by descending on ropes. The end result of this work is a detailed schedule of current condition of every member of all four viaducts. This work was checked against previous inspections to identify any advance of deterioration. This inspection and scheduling work was facilitated by the thorough and detailed drawings of all four viaducts that were prepared by A Suchanski and S L Dsouza for the NZ Historic Places Trust in 1989.

In addition to the above, the Conservation Plan work included detailed photography of the viaducts, a geotechnical assessment and extensive research into the history and relevance of the viaducts.

5. CONDITION

The viaducts are in surprisingly good condition given their age. The remedial work and vegetation clearance carried out by the Trust since 1990 has clearly slowed the deterioration process and restored stability to the viaducts. There are however several common deterioration processes underway on all four viaducts. These are:

- Site instability: Continued down cutting of the streams will begin to undermine foundations near the stream edge.

- Pile rot and settlement: Several hardwood piles embedded in the alluvial gravels have deteriorated to the point where some are non existent below ground level.

- Weathering: This inorganic process of deterioration of the wood under solar radiation is evident on the viaducts but is not yet a threat.

- Sapwood Loss: The decay and almost complete loss of sapwood is most evident on the Sand Hill viaduct where round timbers were used for vertical pier members. This loss has resulted in joint loosening.

- Butt-end centre rot: Fungal attack of the less resistant pith wood is a characteristic of eucalypt logs. Several of the longer timbers are suffering from this type of rot and the remedial work carried out in 1993 on the Percy Burn viaduct was predominantly for the purpose of addressing this issue.

- End Rot: Fungal rot enters hardwood timbers along the more permeable longitudinal grain from exposed ends. Several pier caps suffer from this, however good construction detailing in most places (except the horizontal pier bracing) has minimised the structural impact of this effect.

- General Rot: Where soil and vegetation has accumulated against the structural timbers, the damp conditions have been more conducive to rot. This is most prevalent in the lower shaded sections and in the timber sills that are in direct contact with concrete foundations.

- Gutter Rot: This describes the rot that occurs along the tops of beams along the line of sleeper spikes. Iron promotes fungal decay and when the spikes rust away, they provide a path for moisture and fungal attack to the more prone pith wood inside the beam members. Gutter rot is the predominant threat to the main beams of the viaducts.

- Missing members: The viaducts are generally intact apart from the original decking, barriers and horizontal bracing timbers. Pilfering of items from the structures has not been a problem. The loss of the longitudinal bracing from the Percy Burn viaduct makes it prone to damage or collapse under severe earthquake.

- Rusting of Rail bracing: The original tramline bracing has survived well, probably due to the cooler temperatures of the site, but there is evidence of rusting arising from exposure to salt laden winds on the more exposed parts of the viaducts.

- Rusting bolts and fixings: The forged bolts and fittings have become rusted, and in many cases the square nuts are almost completely deteriorated.

Figure 5. *End rot at the ends of pier columns*

Figure 6. *Previously repaired pier columns with laminated spliced timber*

6. REMEDIAL OPTIONS

Any remedial work carried out on heritage structures needs to be undertaken in accordance with the general principles and conservation processes outlined in the ICOMOS New Zealand Charter for the Conservation of Places of Cultural and Heritage Value. Where the existing structural fabric is severely deteriorated, a major dilemma exists as to whether to provide introduced structural support for the original fabric, or to replace the original fabric with similar materials and structural form. The ICOMOS principles drove the decision process surrounding the establishment of recommendations for remedial work.

The remedial work options considered for the Port Craig Viaducts included:

- External Support: Provision of external support for the self weight of component members. This option was discounted in most instances because of the extensive introduced support structure that would be necessary and the desire to avoid cluttering the slenderness and simplicity of the original structural form of the viaducts.

- Lamination: Removal of rotted portions of original hardwood timbers and replacement of these with spliced laminates. The 1994 and 1999 work included this type of work and it has been highly effective in maintaining structural integrity and was achieved at reasonable cost. Whilst this approach has provided a structurally successful solution which assimilates the original structural form of the viaducts, the appearance of large numbers of bolted and spliced timbers detracts from the clean simple original appearance. There is a concern that if this approach is continued, the viaducts would take on the appearance of "giant lego". For this reason, continuation of pinus radiata splicing is regarded as an option that should be pursued only if more visually acceptable options cannot be adopted.

- Replacement: Removal of rotted sections of members and/or whole timber members that have significant rot and replacement of these with durable eucalypt hardwood timber of the same dimensions as the original. This option is only possible if there is an available supply of suitable large cross section hardwood timber. With the replacement of several hardwood timber railway and road bridges underway in NZ, there is potential to reserve suitable timber from the structures that are being removed. These structures often contain sound durable hardwood that with suitable treatment, can be expected to remain serviceable for a significant time.

- Void Filling: Where pipe rot and gutter rot is present in members but there is still sufficient structural capacity in the remaining timber to carry the self weight and pedestrian loads on the structures, there is potential to treat the remaining timber with preservative foam. There is also an option to then fill the cavities with polyurethane foam filler. This foam filler provides added strength and stability to the member as well as reduces the tendency for any preservative to come out of the wood into the cavity.

- Surface Preservative Treatment: Surface rot is best controlled by keeping the timber surfaces dry and by applying a preservative that inhibits fungal attack. Spray application of copper naphthenate emulsion to all exposed timber surfaces is the recommended primary means treatment for fungal attack for the viaducts.

- Internal rot treatment: Where internal cavities are accessible, treatment with preservative foam is recommended, however access to most internal cavities in the viaduct timber is extremely difficult. Insertion of boron paste into bored holes at the ends of timber members is recommended. This is more suitable for dry timber and diffuses more readily through timber than copper naphthenate.

- Bolts and Fixings: Leaving existing deteriorated bolts in place and adding new bolts is preferred from the perspective of retaining original structure fabric, however this option is not favoured because, given the nature of the structural joints on the viaducts, there are limited locations for new bolt positions. Hence the recommended approach is to remove all badly deteriorated bolts and replace these with new hexagon head galvanized bolts.

- Steel fittings: Where the original steel fittings are badly deteriorated, replacement of these with new, similarly detailed fittings is proposed. Galvanized finishing will differentiate the new fittings from the original.

- Rusted steel rail bracing: Where rails are badly rusted, replacement of these with similar section rail is recommended. This bracing is critical to the lateral integrity of the structure.

- Steelwork protection: All remaining steel fittings and rails and any new rails are recommended for treatment with Shell Ensis V or Fishoilene. This will retain the original rusted rail appearance, but slow the rate of deterioration.

7. WORK REQUIRED

Urgent remedial work to the worst rotted piles of the Percy Burn Viaduct has been carried out since the investigation work for the Conservation Plan was completed. This work has been successful in stabilizing the structure and rectifying the sideways deformation of the viaduct.

A detailed schedule of remedial work and treatment for each viaduct is included in the Conservation Plan. This includes various combinations of the options outlined above. This work is essential if the deterioration of the viaducts is to be arrested and their survival for more than the next few years is to be assured.

With the replacement of the worst of the deteriorated items and treatment of the remaining original fabric, the Port Craig Viaducts can be expected to remain intact for a further 80 years, provided a programme of inspection, re-treatment and remedial work is maintained.

The estimated cost of the currently recommended remedial work for all four viaducts is $2.02M. This significant sum needs to be raised in the near future if these structures are to be saved. Given the Port Craig Viaducts provide a spectacular attraction and are an important component of the whole Port Craig sawmilling story that entices visitors to the area, it is expected that expenditure on restoration will be returned in the form of profit from tourism revenue for the region.

8. ACKNOWLEDGEMENTS

Thanks is made to Southland's Port Craig Viaducts Charitable Trust who commissioned the Conservation Plan. Special thanks is also due to the following:

- Jim Tillard of Tuatapere who accompanied the inspection visit and worked relentlessly clearing vegetation and soil from the structures.
- Royden Thompson, geologist who made a geotechnical appraisal of the sites.
- Bill Roxburgh and Nathan Meager, Adventure Southland who provided abseil access equipment and managed the abseiling activities on site
- Helen Hall who managed the food and cooking for the team on site.

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Gas Engines in Victorian Industry, 1870-1950

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SUMMARY: *In 1866, the German engineer, Nikolaus August Otto, was awarded a patent for his 'free piston atmospheric gas engine', which he presented the following year at the Paris Exhibition, winning the Grand Prize. It was to become the world's first commercially successful internal combustion engine design. Manufacture of Otto atmospheric gas engines had began in Germany and Britain by 1869 and within five years Otto engines were being used in Victoria. After the introduction of the improved 'four-stroke' Otto gas engine in 1876, the invention was further popularised, becoming an economical and efficient alternative source of industrial power to steam engines for small-scale enterprises.*

Following the 1850s gold-rushes, Victoria had become the key centre of manufacturing in Australia and its industrialists were early adopters of gas engines. In 1880, 5% of all mechanically-powered factories in Victoria were using gas engines and by 1901 the proportion had reached 30%. Although oil engines and electric motors were to provide increasing competition as the newest sources of industrial power, gas engines continued to play a key role in Victorian industry well into the 20th century. The introduction of the suction gas producer was of particular importance, enabling gas engines to be freed from their earlier dependence on reticulated town gas supplies enabling their application in a wide range of rural industries.

KEYWORDS:*Gas Engines; Gas Producers; Industrial Power; Internal Combustion Engines*

1. ORIGINS OF THE GAS ENGINE

Arguably the origins of the internal combustion engine date back to the 1670s, when the Dutch scientist Christiaan Huygens carried out experiments aimed at harnessing the force created by exploding gunpowder in an enclosed cylinder fitted with a piston.[1]

During the first half of the 19th century numerous patents were taken out for various experimental internal combustion engine designs, however, the Belgium engineer Jean Joseph Étienne Lenoir, is generally attributed with having developed the first pratical internal combusiton engine design with his 1860 patent that described a single-cylinder two-stroke engine burning a mixture of coal gas and air ignited by a "jumping spark" from a Rühmkorff coil. Lenoir's engine looked almost identical to standard double-acting horizontal steam engine of the period and the design of most of its components were borrowed directly from steam engine technology, including two slide valves that emitted the gas and air mixture to the cylinder and discharged exhuast gases. Unlike later two-stroke internal combustion engine designs the fuel-air charge was not compressed before ignition and this limited both its efficiency and power output.

On a wave of initial public enthusiasm and publicity a company was floated to manufacture Lenoir engines in Paris and production was also commenced under licence by the Reading Gas Works in London. Fewer than 500 engines were built, however, over the following decade as customers soon found that they were excessively noisy and consumed up to 3 cubic meters of gas per HP-hour making them uneconomic to operate.[2]

Further developing the ideas pioneered by Lenoir and others, the German engineer Nikolaus August Otto developed the first commercially successful internal combustion engine design which he patented in Prussia in February 1866, and subsequently in other German States, Britain, France, the United States and other European countries. The following year Otto and his business partner Eugen Langen publicly demonstrated the engine at the Paris Exposition Universelle where it was independently tested against the Lenoir engine and convincingly won the Gold Medal Grand Prize recording less than half the gas consumption of it's predecessor. Although it also worked on a two-stoke cycle with no compression of the fuel/air mixture before combustion in other respects the two designs were quite disimilar. Otto's design was single-acting with it's single-cylinder encased in an elaborate Grecian Ionic styled column and used a naked flame for ignition instead of a spark. The most important distinction, however, was the free-piston and over-running ratchet mechanism that Otto devised to improve the engine's efficency. This allowed the piston to rise freely under the explosive force of the burning gas, with the motive power being generated only during the downward stroke by atmospheric pressure acting on the upper face of the piston.[3] (Figure 1)

Although branded the ‘rattling monster’ or ‘devil’s machine’ by its detractors, the Otto-Langen free-piston atomspheric engine did prove to be the first gas engine design that could successfully compete with steam engines, particularly for small power applications. Its main disadvantage was the noise and vibration created whenrunning and its tendency to crack foundations from the recoil force or eject the piston violently out the top of the cylinder when it misfired.

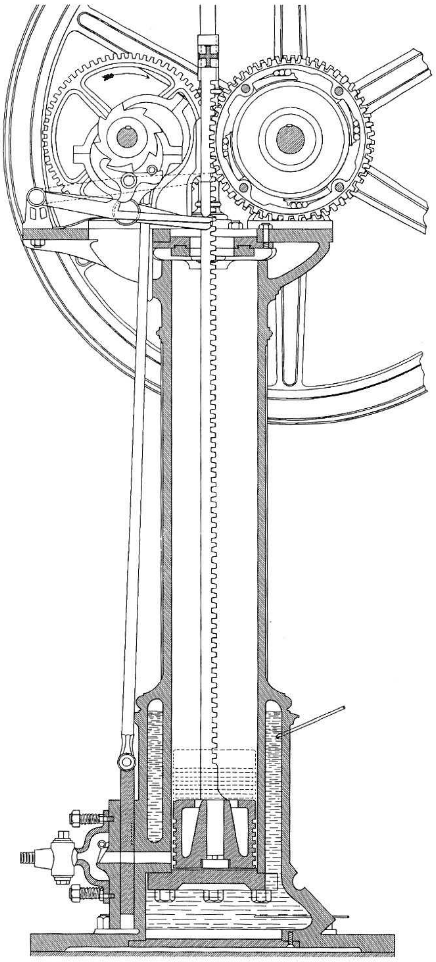


Figure 1. *Sectional View of the Otto-Langen 1866Free-Piston Atmospheric Gas Engine*
Source: Hardenberg, H.O. (1999), p.326

By 1868, Otto and Langen had established a purpose-built factory in Colgne where full scale production of the engines began. In August 1869 Crossley Bros, of Manchester, signed a licence agreement giving them exclusive manufacturing rights for Otto-Langen free piston atmospheric gas engines sold throughout Britain and all British Colonies, including Australia. Crossley's were to become the most significant foreign manufacturer of Otto-Langen engines, producing around 1,300 in total over the next ten years and contributed several of their own patented improvements to the design. This is the first type of gas engine that is believed to have been imported into Australia. Although no original examples used in Victoria have survived, the Powerhouse Museum in Sydney hold an incomplete example, built around 1875.[4] They also hold a rare example of the original Otto-Langen design. Believed to be one of the first ten examples built by their firm N.A. Otto & Co, in Cologne, around 1867, it was acquired by the University of Sydney from Germany in 1914.[5]

It is not known precisely when the first gas engines were imported or set to work in Victoria, but as early as 1873 the machinery merchants H.P. Welch & Co, of Queen Street, Melbourne, were advertising in local press offering “ATMOSPHERIC GAS-ENGINES (Otto and Langen’s patent), manufactured by Crossley Bros, Manchester.”[6]

Newspaper advertisements for new and second-hand “Otto” atmospheric engines suggest that the most common size in use at this time ranged from ¼ to 1 horsepower, while a typical price for a second-hand ½-horsepower engine with tank & fittings was quoted at £80. Another advertisement for a second-hand “Crossley’s patent” gas engine quoted the key selling point “Starts immediately” alongside indicative running costs of “4d daily”.[7]

In 1872, after publically floating the Cologne manufacturing firm as Gasmotoren-Fabrik Deutz AG, Eugen Langen recruited two new staff members who would play a key role in the later development of the Otto engine. Gottlieb Daimler, became prouction manager and was assigned the task of reorganising the factory to cut production costs, while the talented young design engineer August Wilhelm Maybach was set to work simplfying and improving the original Otto-Langen engine design.By late 1876, Maybach had assisted Otto in a complete transformation of the atmospheric free-pistion gas engine into the first ‘modern’ internal combustion engine. Dubbed the “Silent Otto” to emphasise its significantly quieter running characteristics, the new design was publically launched at the Paris Exposition Universelle of 1878, again to great public acclaim.[8]

Unlike it predecessor, the new “Silent Otto” engine had a horizontal cylinder and a more conventional connecting rod and crank coupling between the piston and revolving power shaft. More importantly it operated on a four-stroke cycle and utilised pre-compression of the fuel/air charge in the cylinder before ignition creating significantly better fuel ecomony and smoother running. (Figure 2)

Crossley Bros again obtained the British manufacturing rights, jointly patenting the new design with Otto in Britain in 1877, and would subsequently contribute significant improvements of their own. In Victoria, it was not until 26 June 1878, that a patent for the new design was lodged by Nicholas August Otto of Gas Motoren Fabrik-Deutz for *“Improvements in gas motor engines”*.[9]

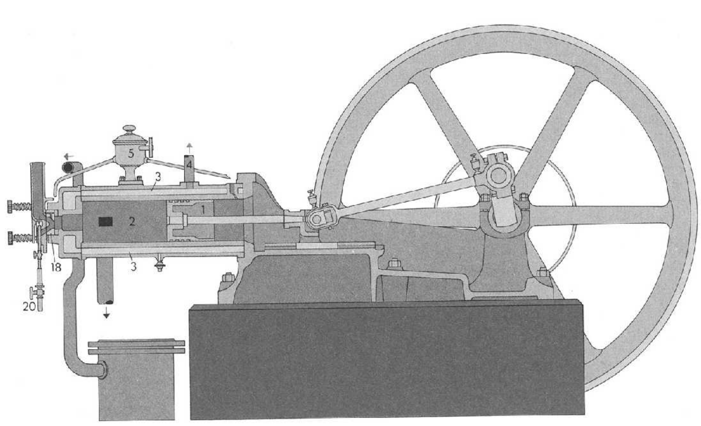


***Figure 2.** Sectional View of the Otto Silent Four-Stroke Gas Engine of 1876*

Source: Strandh, S. (1979), p.143[10]

It is perhaps a testament to the speed of 19th century communications and the extent to which local engineers kept abreast of the latest overseas developments, that in October 1877, the Victorian Government Printing Office send an order to Crossley Bros in Manchester for a 'New "Otto" Silent Gas Engine, one-horse-power, with Water Vessel'. A reply from the manufacturer indicated '*The "Otto" silent Gas Engine has not been sufficiently tested to warrant it being sent - the substitution of an atmospheric Gas Engine is suggested.'* John Ferres, the Government Printer responded with a hand-written annotation

> *'I was induced to ask for the "Otto" Gas Engine because of the excellent testimonials given of it in the "Engineer", "Printer's Register" and other works. I would recommend that the Agent General be requested to send the "Atmospheric" engine instead of the "Otto". - J. Ferres'*[11]

2. EARLY GAS ENGINE USE IN VICTORIAN MANUFACTURING

Gas powered manufacturing works were first separately listed in the *Victorian Statistical Register* in 1878, when 24 installations were recorded. Half were located in the central City of Melbourne municipality and the remainder scattered across three inner suburbs and the country towns of Ballarat, Bendigo, Castlemaine, Geelong and Hamilton.

In October 1879, the Victorian Government exempted *"Engines of which gas is the direct motive power"* from the general 25% import duty levied on steam engines and general machinery.[12] This action, together with the new "Otto Silent" design, appears to have had an immediate impact, with the number of gas-powered factories increasing rapidly from 29 in 1879, to 41 in 1880 and 76 in 1881. By the mid 1880s, Victoria had over 150 factories employing gas engines, representing about 13% of all mechanically powered manufacturing works.[13] (Appendix A & B)

The most significant early concentration of gas engines occurred in the printing industry with printing works, stationery and account-book manufacturers accounting for 75% of all gas engine powered manufacturing works recorded in 1878. Although this percentage would decline over subsequent years, a decade later in 1888, the printing industry still contributed 43% or 106 of the 255 gas-powered manufacturing works in Victoria. The early adoption of gas engines in printing works followed similar trends in the trade in Britain and the United States. The introduction of continuous rotary printing presses, ruling machines (for printing account books and ledgers),power guillotines, binding machines and ink-mixing machines around this time all generated a new demand for mechanical power in printing workshops. Whilst most of the machines were designed to be either manually or mechanically powered, the introduction of a small engine provided immediate benefits in reducing the wages required for manual labour and increased output.

Other Victorian industries that saw early concentrations of gas-powered works included foundries and engineering workshops, boot & shoe manufacturers, clothing factories, aerated water and ginger beer manufacturers, chicory, coffee & spice mills, chaff mills, manufacturing jewellers and watchmakers.

Clothing Manufacturers Beath, Schiess & Co,were a typical example of the early adopters. By 1882, they were employing Crossley gas engines at two factories in Collingwood and another off Flinders Lane in the city, for driving sewing machines and "cutting cloth by machinery, with a machine that has been patented in the colony, a band knife on the principle of the hand saw." The cloth was formerly cut by hand with shears, the introduction of the machinery enabling the proprietors "to lower the cost of production without lowering wages as far as the manufacturer is concerned."[14]

The average installed horsepower of engines in factories employing only gas-power in 1880 ranged from 1.0 to 6.5 horsepower.[15] The machinery employed by many factories in the above industries was limited in its power requirements, typically ranging from ½ to 2-horse-power. In this power range, even the early atmospheric gas engines provided a more cost-effective alternative to steam power. The gas engine also had a natural advantage in that it was small enough to fit within a cramped inner city workshop, while the vertical format and limited weight of many early gas engines allowed them to be bolted directly to the floor alongside printing machinery, sewing machines or other equipment, with no need for a separate boiler house or large external brick chimney.

3. GAS ENGINES AT THE EXHIBITIONS

Just as the earlier international exhibitions, hosted in London, Paris, Philadelphia and Vienna had become showcases for the world's latest technological innovations, so the Intercolonial and International Exhibitions held in Melbourne during the late 19th century were a key vehicle of the dissemination of the latest developments in mechanical marvel. Many of the thousands of visitors who thronged through the pavilions of Melbourne's exhibitions probably had their first experience of witnessing a gas engine at work during the exhibition.

At the Intercolonial Exhibition held in Melbourne in September 1875, W.H. Masters & Co displayed a Raymond sewing machine driven by a "Nicholson's sewing-machine *engine*" which it was claimed could be operated at the cost of only "halfpenny per hour with gas, and a penny burning kerosene". By way of justification the commentary added "When it is borne in mind that the constant use of the sewing machine treadle is injurious to the female constitution, the value of this miniature engine will be recognised."[16] It is possible that this was actually a hot air engine rather than an internal combustion engine.

As early as 1879, just a year after the "Otto Silent" engine was publicly displayed for the first time at the Paris exhibition, local agents Messrs Bright Brothers & Co,offered the loan of an "Otto" silent gas engine for driving working models on display at the Intercolonial Juvenile Industrial Exhibition in Melbourne.[17]

At the Melbourne International Exhibition held from 1 October 1880 to 30 April 1881 in the new Melbourne Exhibition Building, gas engines were a key feature amongst the mechanical exhibits. In the British Court, Bright Brothers & Co, of Flinders St displayed three horizontal gas engines for the latest "Otto Silent" design manufactured by Crossley Brothers, Manchester, rated in the sizes of 1, 3½ & 6 nominal horsepower. In reporting on the exhibits *The Argus* noted purported advantages of the gas engine as being: *"less objectionable from an insurance point of view than the steam engine", "ready at a moments notice, require no attention except occasional cleaning and oiling"* and *"cost at the present price of gas in Melbourne about twopence per horse-power hour* ... [which] *hardly exceeds the cost of coal for small steam engines."*[18]

The smallest "Otto Silent" gas engine made Crossley Bros at this time was the half-horsepower model. For those requiring mechanical power in smaller amounts, the exhibits also included an example of Bisschop's vertical gas engine, rated at two manpower (equivalent to about ¼ horsepower), shown by the machinery merchants McLean Brothers & Rigg. Another slightly larger gas engine on the same principle, made by Mignon & Rouart of Paris, was shown in the European annexe. Invented by the Dutch-born Paris engineer, Alexis de Bisschop, this engine was somewhat of a technical oddity, having more in common with small hot air engines than later gas engines. Technically it was a single-acting atmospheric engine like the Otto-Langen design operating on a two-stroke cycle, but incorporated a slider-crank mechanism that provided a much simpler and quieter running motion than Otto's ratchet mechanism. (Figure 3) Although patented in 1875, "teething problems" delayed production and it made its first public appearance at the Paris Exhibition. Mr Andrew of J.E.H. Andrew & Co, Stockport, was so impressed when he saw the engine running at the exhibition that he purchased the British manufacturing rights. Despite their high gas consumption (in some cases up to seven times that of the Otto-Langen engine of equivalent power) the simplicity of construction and low cost of the Bisschop engine saw it remain a popular source of mechanical power in small workshops until displaced by the electric motor in the 1890s. Over a 16 year period from 1878-1894, some 2,000 Bisschop engines in sizes from 1 to 4 manpower were made at the Stockport Gas Engine Works and quite a number appear to have been sold in Australia. Surviving examples exist in the collections of both the Powerhouse Museum and Museum Victoria.[19]

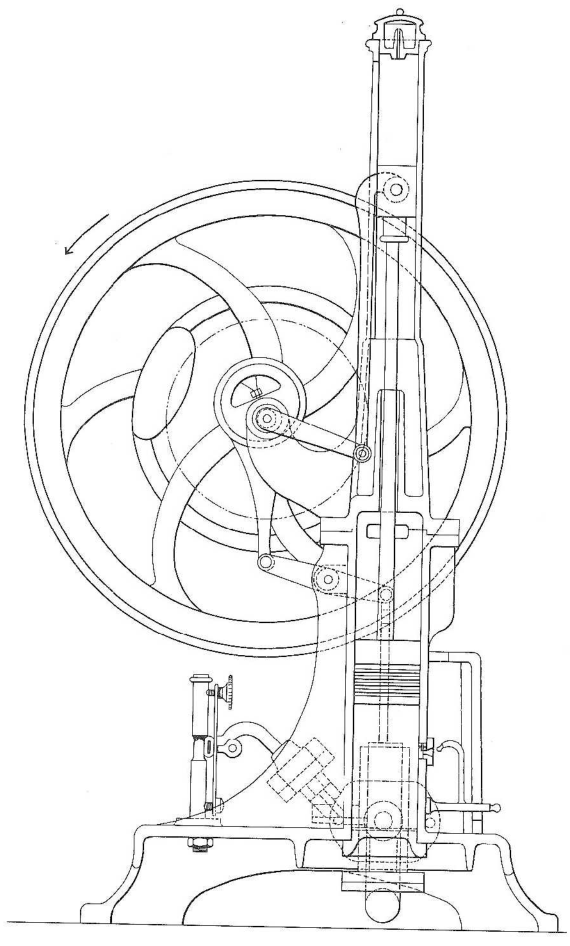


Figure 3. *Sectional View of the Bisschop 1875 Atmospheric Gas Engine*

Source: Hardenberg, H.O. (1999), p.380

The Engineer's Conversazione, was an early example of a more specialised trade fair organised by the newly formed Victorian Engineers' Association in December 1883. Once again hot air engines were featured amongst the variety of mechanical exhibits, but this time *"the well-known Otto silent gas-engine* [was] *conspicuous by its absence"*. Instead two new designs made their first appearance in Victoria. The first was a 2-horsepower engine made to Dugald Clerk's patent design by Thomson, Sterne & Co, of Glasgow, exhibited by Mr Dempster of Post Office Place. To avoid infringing Otto's patent, Clerk's design was based on a two-stroke cycle and utilised a double cylinder configuration, in which the gas and air charge was drawn initially into an auxiliary cylinder, known as the displacer, and was slightly compressed before being transferred to the power cylinder where ignition took place. Both cylinders were driven from the same crankshaft, with the displacer crank about 90 degrees in advance of the power cylinder crank. The design achieved moderate commercial successful over the following decade. Mr Dempster also displayed a two-manpower Bisschop's engine made by J.E.H. Andrew & Co.[20]

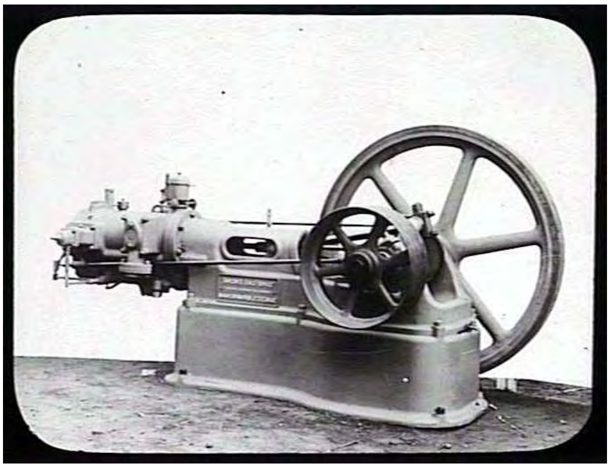


Figure 4. *Tangye Robson Two-Stroke Gas Engine*
Source: Museum Victoria

The second new design was another two-stroke engine, manufactured by Tangye Brothers, of Birmingham, to a design patented by James Robson of Surrey, England, in 1877. Tangyes developed the original Robson patent into a practical design, which they first exhibited at Bingley Hall, Birmingham, in 1880. It differed from other early gas engines in that it employed a single cylinder that was enclosed at both ends much like a steam engine. One end of the cylinder worked as a pump to compress the charge of air and gas, forcing it into a receiver from where it was admitted to the power end of the cylinder at the end of the exhaust stroke. Not long before the exhibition Tangye Bros had opened their own Melbourne sales office in Cornwall House, Collins Street, from where they sold a wide range of machinery from gas engines, steam engines and boilers to hydraulic jacks, pulley blocks, crab winches, pumps and lathes. They continued to manufacture the "Robson's patent" gas engine until after the Otto patent expired when they switched to a four-stroke design and continued to be a major supply of gas engines in Victoria well into the 20th century.[21] (Figure 4)

By far the greatest mass display of gas engines ever presented in Victoria was produced for the Melbourne Centennial International Exhibition, which ran from 1 August 1888 to 31 January 1889. Crossley Bros Ltd, of Manchester, through their Melbourne agents Alex Cowan & Co, mounted an exhibit of no less than 13 "Otto" gas engines ranging in size from their smallest ¼-horsepower vertical engine to a large horizontal engine rated at 9 nominal horsepower, but capable of developing 18 indicated horsepower. Four of the smaller engines shown were examples of Crossley's compact "Domestic Motor", a vertical single-cylinder design in which the cylinder was enclosed in a simple tapered cast-iron column supporting an overhead crankshaft and flywheel. Designed specifically to occupy the minimum possible floorspace, the Crossley "Domestic Motor" was a direct successor to the earlier vertical Otto-Langen design and like the former was a popular power source in small workshops. The Powerhouse Museum collection holds two examples of the Crossley "Domestic Motor" and Museum Victoria holds an engine of very similar design made by Purnell, of Scotland.[22]

Amongst the horizontal Crossley "Otto" engines shown were two examples, rated at ¾ & 2-horsepower, incorporating the latest improvements "never before exhibited". These modifications were added by Crossley to the origin Otto design and patented in Victoria in July 1888. They included an incandescent hot-tube for ignition, heated by a small Bunsen burner flame; modern style poppet valves in place of earlier slide valve; and an inertia governor allowing speed adjustment of up to 100 rpm, in place of the order style revolving governor. Other horizontal Crossley "Otto" engines on display were shown working a variety of machinery including an electric dynamo, a two-throw pump feeding an illuminated water fountain, a 'Lightfoot's' dry air refrigerator, a small goods hoist and a working display of bakers' and confectionery making machinery.[23]

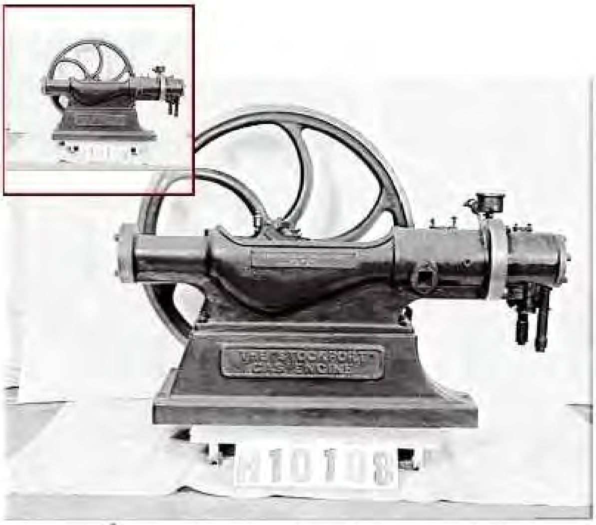


Figure 5. *Stockport Two-Stroke Horizontal Gas Engine*
Source: Powerhouse Museum, H10108

Nearby J.E.H. Andrew & Co Ltd, displayed seven of their tandem 'Stockport' gas engines based on Dugald Clerk's patent, in sizes rated at ¼, ½, 1, 2, 4, 6 and 8-horsepower. Two of these engines were shown driving dynamos of the Australian Electric Co, producing power for lighting of the exhibits at night (the exhibition remained open till 9 pm over the summer months) and for driving an electric motor powering other machinery exhibits. Two of the smaller 'Stockport' engines were also fitted with latest hot-tube ignition, which dispensed with the slide valve previously required to admit the flame into the cylinder to attain combustion. Andrew & Co had commenced making their 'Stockport' two-stroke engines in 1882, producing over 6,000 in total by 1888 for "electric lighting, hoisting, printing machinery & innumerable other work", in sizes from ¼ to 100-horsepower. They would continue building them until 1892, when production was switched to the "Otto" four-stroke design. A partially incomplete example of the Andrew & Co 'Stockport' tandem engine is held by the Powerhouse Museum.[24] (Figure 5)

Over the decade following the Centennial Exhibition, the number of gas engine powered factories in Victoria would double - from 263 to 520 – and the proportion of mechanically-powered factories using gas engines rose from 15% to 20%. Over the same period the number of steam-powered factories in Victoria declined by 11% - from 1,403 to 1,247.[25] (Appendix A & B)

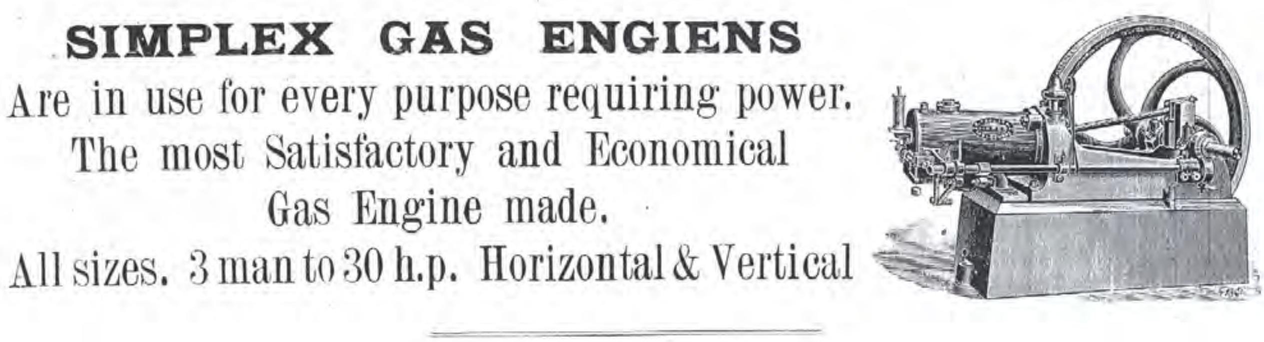
4. MANUFACTURE OF GAS ENGINES IN VICTORIA

Given the strength of Victoria's local engineering industry dating back to the 1840s, it is surprising that it took almost a quarter of a century before local firms began building gas engines. The first locally made steam engine had been turned out by Langlands Foundry in 1845, just four years after the introduction of steam engines in Victoria. By 1860 over a dozen firms were building steam engines, including several on the goldfields at Ballarat, Bendigo and Castlemaine.[26]

Early gas engine designs were based on steam engine technology of the period and shared many common components and features so there was no technical reason why local firms could not have built gas engines once they'd mastered the basic operating principles. Initially the demand for gas engines was probably too small to warrant local manufacture, but by the mid 1880s there was a thriving repair trade in gas engines providing a basis that could have been extended into manufacture, as had earlier happened with steam engines. It appears that it was the risk of patent infringement – either real or imagined – that initially deterred local manufacture.

Curiously no evidence has been found that Otto's original atmospheric free-piston design was ever patented in Victoria, however the later "Silent" four-stroke design was covered by Otto's Victorian Patent No.2533 of 26 June 1878. Both Crossley Bros and Gasmotoren-Fabrik Deutz vigorously defended their patent rights with threats to sue and, in many case overseas, infringement lawsuits. Though there is no evidence of any lawsuits being pursued against Australian firms, the "patented" aspect of the design featured heavily in local advertising and together with Crossley Bros dominance of early gas engine sales in Victoria (estimated to have been as high as 80% over the first decade), this created the impression that local manufacture was not possible.[27]

The exemption of gas engines to the 25% import duty from October 1879, certainly created further disincentive towards local manufacture, and had the unintended side effect of undermining demand for small steam engines. William Brown had been operating a thriving engineering business from 1857 in Collingwood and later from a central city workshop making small stationary steam engines for a variety of customers. In 1882, he complained to the Royal Commission on the



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Tariff that he had not received a single steam engine order since the duty on gas engines was removed three years earlier.[28]

The deluge of litigation around Otto's 1876 patent in Europe, eventually saw the patent overturned in Germany in 1886, but it remained in force in Britain until 1891 and in Victoria until 1892.[29]

E. Coulson & Co are the earliest recorded firm known to have manufactured gas engines in Victoria in any significant numbers. The business was established in 1893 by Edmund Coulson who began operating from a small workshop at 88 Little Collins Street West, advertising as:

[30]

> **E. COULSON, GAS ENGINE and PRINTERS' ENGINEER**, 88 Little Collins-street west.
>
> Specialist for the removal and erection of gas engines and printing machinery. Repairing in all departments. Slide valves re-surfaced. Orders by post promptly attended to; and work guaranteed.

Figure 6. *Excerpt from an E. Coulson Advertisement for 'Simplex' Gas Engines, circa 1900*
Source: Museum Victoria

By 1896, Coulson had relocated to larger premises at 116 A'Beckett Street, Melbourne and begun manufacturing his own design of gas engines under the "Simplex" brandname.[31] In 1897, Coulson applied for two Victorian patents, No.14166 for *"Improvements applicable to gas and oil engines"* and No.14530 for *"Improvements in hydro-carbon engines, partly applicable to gas engines."*

By 1898, Coulson had established a display stand at the Royal Agricultural Society's showgrounds, where he mounted an impressive display of portable and stationary patent "Simplex" gas and oil engines. It was reported that E. Coulson & Co were making portable & stationary gas engines in sizes of 1 to 20 BHP, with *"over 140 of these engines in use in this colony"*. The report also noted that *"This engine is of the latest improved tube ignition type, fires under high compression without timing valve. It is very economical and complete."* The report also stated that "Simplex" oil engines, in sizes 2-manpower to 9 nominal horsepower, vertical or horizontal, where also offered, although *"Owing to the very large demand for this firm's "Simplex" Gas Engine during the past 12 months, the oil engine have not been pushed to the extent its merits justified, but with increased facilities now offered, oil or gas engines can now be produced in any quantities for quick dispatch."*[32] (Figure 6)

By August 1899, E. Coulson was advertising "Simplex" gas engines from 3-man to 30-horsepower, with the claim that over 200 were at work in Victoria. At the Melbourne Show the same year it was noted that his "Simplex" oil engine was in it's third year of "practical working". By 1900, advertisements claimed that over 300 "Oil, Gas & Steam Engines" were at work. By 1901, "Simplex" gas engines of up to 50 horsepower were offered, however, thereafter production appears to have concentrated largely on portable & stationary oil engines. In 1905, Coulson undertook a somewhat novel contract to refit the Port Phillip Bay steam ferry *PS Queen*, that involved removing the vessel's steam plant and paddlewheels and fitting in its place an imported suction gas producer and 160 horsepower gas engine with screw propulsion.[33]

The second Melbourne firm to become involved in the local manufacture of gas and oil engines was operated by H.V. Hampton. Hampton had a long association with the engineering trade in Melbourne dating back to 1872, having worked for a period as manager for Mr J. Crighton, engineer, Victoria Street, Carlton where he was involved in the manufacture, installation and repair of a variety of machinery for the sawmilling, brick-making, printing, tile-making, pipe-making, and jam & confectionery industries. In 1884 he established his own business and by 1890 was operating the Victory Gas Engine & Engineering Works in Bright Street, South Melbourne, near Princes Bridge, offering "to Execute Repairs to all kinds of Engines and Machinery" with "A stock of engines on hand." – which presumably were imported.[34]

While the precise date at he began making gas engines is unknown it appears to have been around 1897, after moving to new premises on the corner of Elizabeth & Therry Streets, Melbourne. Like Coulson, he first mounted a display at the Royal Melbourne Show in 1898, exhibiting both oil and gas engines of his own make. In a report from the Show it was noted that *"An oil engine on a somewhat different principle to those at present in use is also among the latest inventions of Mr Hampton's establishment. The simplicity of this engine cannot be surpassed, being worked with the aid of only one valve."* The report also noted that:

> *"An improved type of gas engine know as the "Victory" was also displayed. This kind of engine is highly appreciated at butter factories, as there is an entire absence of smoke or dust. Steam (sic) can be raised in a few minutes, and is easily regulated without fear of explosion. Within a very short space of time 300 odd engines have commanded a ready sale."*[35]

In 1899, H.V. Hampton applied for a Victorian No.15882 for *"Improvements in oil explosion engines"* and it was reported that *"The Victory Gas Engine can be found working in almost every part of Melbourne and suburbs, and the Victory Oil Engine is coming rapidly to the front…"*. Aside from the engines, Hampton also carried on a thriving general engineering business making wood-working machinery, jam manufacturers' machines, canning machinery and the "Victory" bone crusher and "Daisy" Green Bone Cutter that found a ready demand with poultry farmers.[36]

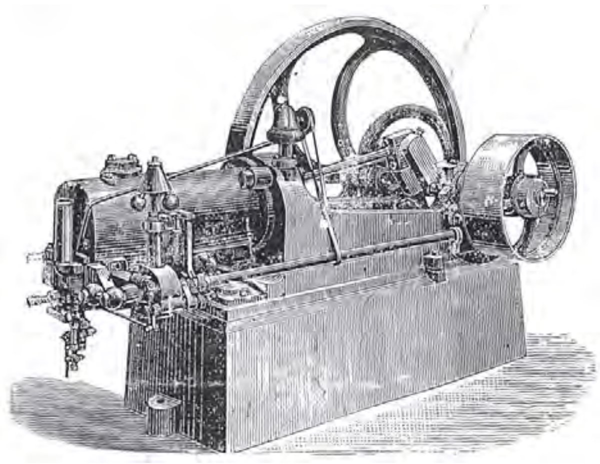

Figure 7. *H.V. Hampton Gas Engine, circa 1900*
Source: Museum Victoria

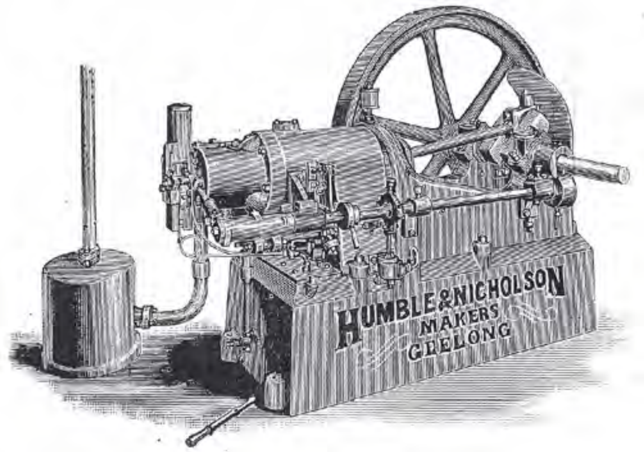

Figure 8. *Humble & Nicholson Oil Engine, circa 1900*
Their gas engines were made to a similar design.
Source: Museum Victoria

Most of both E. Coulson's and H.V. Hampton's early output of engines appears to have found customers in the small workshops and factories of printers, boot & shoe makers, clothing manufacturers, engineering works, food manufactories and butchers around central Melbourne and inner suburbs like Fitzroy and Collingwood. After 1901, the output of both firms concentrated largely around portable and stationary oil engines, with country industries becoming increasingly important customers. Several examples of the oil engines made by both firms have survived in private collections, but no surviving gas engines have been found.

William Humble & Ward Nicholson, of the Vulcan Foundry, Geelong, also applied for a Victorian patent for *"An improved oil or gas engine"* in 1899. Founded by Humble & Nicholson with John Simmonds in 1861, the Vulcan Foundry was one of Victoria's largest engineering works by the 1890s manufacturing a wide range of mining machinery, steam engines, boilers, agricultural and railway equipment and other products. They had also developed a reputation for pioneering new products, being amongst the first firms in Victoria to manufacture portable steam engines, compound steam engines and refrigerating machinery. By August 1899, Humble & Nicholson were advertising "Oil and Gas Engines, to requirements". It is not known how many oil and gas engines Humble & Nicholson built. The last identified advertisement for their oil and gas engines is dated 1900 and no known examples have survived.[37]

During the first decade of the 20th century several new engineering firms were established in Victoria that went on to develop significant reputations manufacturing petrol, kerosene and oil engines. Only one of these businesses is known to have also made gas engines. In June 1911, A.H. McDonald & Co, of Burnley Street, Richmond were awarded a contract by the State Rivers & Water Supply Commission of Victoria, to manufacture a 20 horsepower single-cylinder vertical suction gas engine and gas producer, to drive a water-pump for the Wycheproof Town Water Supply, at a cost of £405/10/2. Apparently it was made by the firm at a loss, perhaps because of inexperience or a desire to establish a new product line. The engine gave over a decade of reliable service pumping 10,000 to 12,000 gallons per day against a head of 120 to 130 feet while consuming only a bag of coke a day. Later the same year an 80 horsepower four-cylinder gas engine with the same basic cylinder design was manufactured for an unknown customer and McDonald's also built two 10 horsepower gas engines for driving machinery in their own works which operated on town gas. A small number of additional gas engines were built by McDonald's over the years up to 1921 but they never became a substantial product line. Instead the firm developed its reputation and success on the manufacture of stationary petrol engines and tractors, diesel engines and diesel road rollers, with the latter product line produced up to 1985.[38]

5. GEOGRAPHIC DISTRIBUTION OF GAS ENGINE USE

The geographic distribution of gas engines in Victorian manufacturing during the early decades reflected both the main areas of concentrated manufacturing activity and those areas within the distribution area of established gasworks. Reticulated town gas produced by retorting black coal in gas works was the only economical source of gas for motive power until at least the 1890s.

From 1878, when gas engines were first recorded in the *Statistical Registers*, until the mid 1880s, between two-thirds and three-quarters of all gas engines recorded were working in the Melbourne metropolitan area, concentrated mostly in around the Central Business District and inner suburbs.

In the country districts the early use of gas engines in manufacturing was concentrated in larger towns which already had established gasworks. It was not until 1888, that any gas engines were recorded at work in towns without gasworks.

By 1890, the main concentrations of gas engines outside Melbourne were in the regional cities of Ballarat (14), Bendigo (13) and Geelong (9), all major regional manufacturing centres. The somewhat unexpected exception was Warrnambool, with 10 gas-engine powered factories, perhaps reflecting the early predominance of clothing manufacturers in the south-western coastal town which would later become the home of the famous clothing firm Fletcher Jones. All other regional towns and shires had no more than 4 gas-powered factories and in total only 25% of gas-powered manufacturing works were situated outside Melbourne.

Within the Melbourne metropolitan area, it was the City of Melbourne municipality, encompassing the Central Business District and inner areas of West Melbourne, Carlton, East Melbourne and Jolimont that had the greatest concentration of gas engines. The inner city was also the most concentrated manufacturing precinct, with around 20% of all Victoria's factories during the 1870s and 1880s, but it also claimed a disproportionate share of gas engines – between 45 and 66% of all gas-powered factories throughout these decades. Given the nature of inner city industry before 1900, this trend was understandable. Much of the inner city was a maze of small factories and workshops nestling cheek by jowl along the city's back lanes and alleyways, often in close proximity to warehouses, showrooms and retail outlets. Most of these businesses had neither the space to house a steam engine and the necessary adjuncts of a boiler and large brick chimney, nor sufficient machinery to justify employing steam power.

Outside the inner city, it was predominately the inner suburbs of Collingwood, Fitzroy, North Melbourne, South Melbourne, Richmond and Prahran that had the most significant concentrations of gas engines by 1890. Collingwood and Fitzroy both had significant concentrations of clothing and footwear factories, while Richmond and Prahran had lots of clothing and food manufacturing works and South Melbourne had engineering, joineries and woodworking shops. All these industries were early adopters of gas engines.

While the overall number of steam powered factories in Victoria witnessed a 10% decline during the 1890s (from 1,417 to 1260), gas power witnessed its strongest decade of growth, rising from 323 to 630 works. In the City of Melbourne municipality the number of gas-powered factories exceeded the number of steam-powered factories by 1895.

By 1901 gas power had reached a peak were it was utilised in 30% of all mechanically-powered factories, but challenges from new emerging power sources were on the horizon. Electric motors were first recorded as a source of factory power in the 1895 *Statistical Register* and by 1901 there were 42 factories using electric power – mainly in the inner city where access to the emerging power supply grids was readily available. Although reticulated electricity supplies were available in the Melbourne central business district from the mid 1880s and in the major regional cities of Ballarat, Bendigo and Geelong a decade later, manufacturers were initially slow to adopt the new power source. At this time most of the supply was distributed as direct-current, which was ideally suited for the connection to electric motors, but early power supplies were designed primarily for lighting, and customer tariffs were set too high for electricity to effectively compete with either steam or gas engines, despite the convenience. In March 1902, the Metropolitan Gas Co introduced a 20% tariff reduction on gas used for driving gas engines after the Melbourne City Council's Electricity Supply Department began selling electricity for motive power at a lower rate than the standard lighting tariff.[39] Within another decade there would be over 1,000 electric motor-powered factories in the State, making it second only to steam power in importance (Appendix A & B).

Oil engines had also began make in impact as another alterative source of industrial power for rural and inner city manufacturing, with 59 oil engine powered factories recorded by 1901. While oil or liquid-fuelled internal combustion engines rapidly gained a foothold in rural industries like farming, their role in manufacturing was more gradual, taking almost three decades to overhaul the number of gas engine-powered factories.[40]

Despite the number of gas engines in use by the first decade of the 20th century, most installations remained comparatively small, averaging just 6.2 horsepower in 1905, with typical installations ranging from 1 to 10 horsepower. By comparison, the average steam power installation in factories was 33.4 horsepower and even electric powered factories averaged 7.5 horsepower. Gas power was still predominately the motive power of choice for smaller factories and workshops with 10 or less employees, but this was about to change as Victoria entered the second era of gas engines.

6. SUCTION GAS PRODUCERS

While electricity was rapidly becoming the motive power of choice for inner city factories during the first decade of the 20th century, another technological change was afoot that would extend the use of gas engines for another three decades and transform them from a compact low cost power source for inner city factories and workshops into an efficient cost effective power source for many rural industries. During the decade from 1905, the combined horsepower of gas engines used for motive power in Melbourne's metropolitan factories increased from 3,827 to 10,560, while in country towns the growth was even more dramatic rising from 686 to 7,315 horsepower. The total number of gas engine powered manufacturing works in Victoria peaked at 883 in 1913 and thereafter began a gradual decline, however, the combined horsepower of these installations continued to rise for another decade peaking at around 19,330 horsepower in 1920. This trend saw the average horsepower of gas engine installations used in Victorian manufacturing increase from less than 5 horsepower in 1905 to 25 horsepower by 1919.

This transformation was largely brought about by the introduction of the gas producer – a free standing self-contained unit that could generate gas for motive power directly from any carbon-based fuel at a cost far cheaper than the tariff for coal gas or town gas supplied by gas companies. Whilst the process of producing combustible gas through the burning of anthracite (black coal) or coke with a limited air supply had been known since the late 18th century, it was the British engineer Joseph Emerson Dowson who first patented a practical gas producer in 1878. After further experimentation Dowson demonstrated his gas producer running a small 3 h.p. Ottto gas engine at a meeting of the British Association for the Advancement of Science at York in 1881. The British patentees of the Otto gas engine, Crossley Bros of Manchester, were sufficiently impressed to assist in the further development of the concept and in 1882 when they established their new gas engine manufacturing works at Pottery Lane, Openshaw, in east Manchester, the works were powered by a 150 horsepower gas engine plant of their own make supplied by three Dowson gas producers.[41]

The original Dowson gas producer design was a pressurised system that forced steam generated in a small auxiliary boiler together with a limited air supply into a retort burning anthracite, producing a combustible gas that consisted of about 49% nitrogen, 25% carbon monoxide, 19% hydrogen, 5% carbon dioxide and 1% methane and other hydrocarbons. The gas had a calorific value of about 1,400 calories (5.55 BTU) per cubic metre.

Initial fuel consumption rates of around 2 lb anthracite per engine BHP-hour were produced but by the mid 1880s this had been reduced to around 1.4 lb per BHP-hour.[42] The resulting gas was much lower in calorific value than convention coal gas, but could be made at about one-tenth of the cost.

In 1891, a further improvement to the gas producer was initiated when the French engineer M. Léon Bénier, patented the idea of using the suction from a gas engine to draw the air and steam through the gas producer. In his first practical design demonstrated in 1894, a reciprocating air pump coupled to the crankshaft of a two-stroke gas engine sucked gas from the producer with each stroke and forced it into the engine cylinder on the return stroke.

Other engineers subsequently refined the concept – dispensing with the separate air pump and its attendant friction load and instead using the intake stoke of a four-cycle engine to suck the gas through the producer. Further refinements were also made to the way the water was vapourised into steam, the point where the steam and air were admitted into the retort and the temperature of the incoming air in order to optimise the calorific value of the gas produced, An improved scrubber was also added to remove tar and dust and cool the gas. The resulting "suction gas producer" had the advantage that it dispensed with the separate steam boiler and gas holder required by the original Dowson design and was by nature self-regulating, in that the volume of gas produced was in direct proportion to the work being done by the engine. A greater load on the engine increased the suction at the engine intake, which in turn drew more air and steam through the producer generating gas at a faster rate, while when the engine dropped back to an idle, suction dropped off and gas generation correspondingly fell.

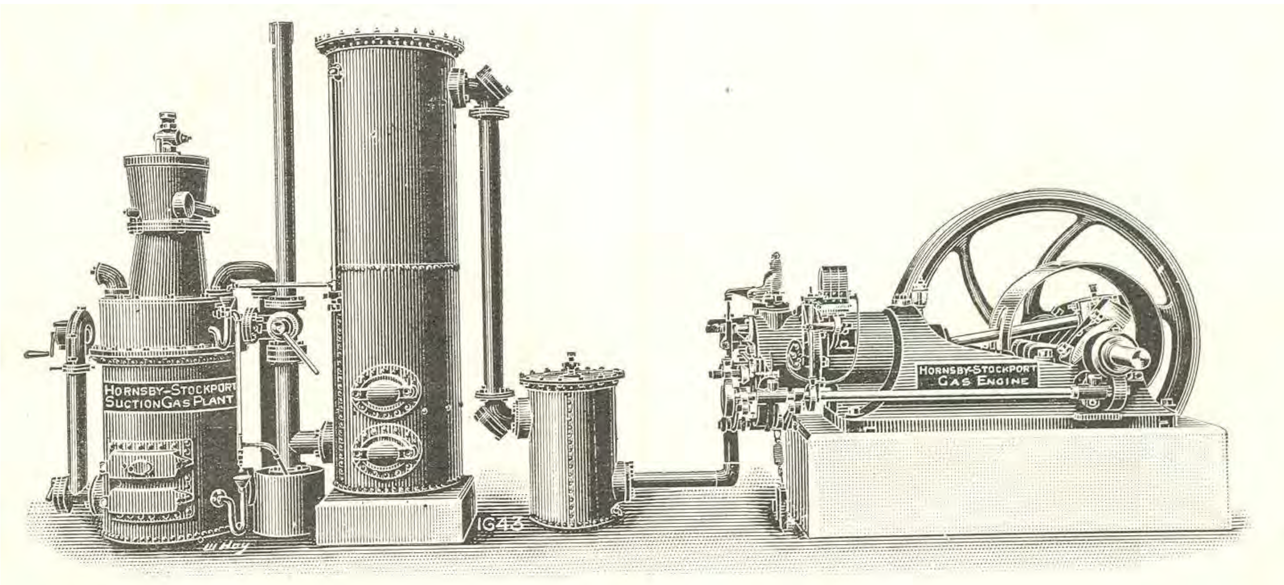

Figure 9. *A Typical 'Hornsby-Stockport' Suction Gas Producer & Gas Engine, circa1905*
Source: Museum Victoria

Suction gas producers also had an additional safety feature in that because they operated under a partial vacuum there was less risk of noxious carbon monoxide or explosive gases leaking than in the earlier style of pressurised gas producer. Suction gas producers were also more versatile as they could be successfully run on cheaper fuels like charcoal, brown coal briquettes, fire-wood and even saw-dust, as well as the anthracite coal and coke used in early pressurised gas producers.

Suction gas plants also had another distinct advantage because as the size of the units increased, thermal efficiency and fuel economy improved, further reducing operating costs. For gas engines running on town gas there was little reduction in gas consumption per BHP-hour with increasing engine size and operating costs remained relatively fixed. Whereas gas engines running on town gas had predominately been adopted by small workshops and factories with limited power needs, once suction gas plants became available these were a positive incentive to increase the horsepower of installations. For over a decade, suction gas engines would provide the very lowest cost of power for large installations.

By 1905 several of the leading British gas engine manufacturers including The Campbell Gas Engine Co Ltd, of Halifax; Crossley Bros Ltd, of Manchester and Tangyes Limited, of Birmingham were offering suction gas plants in Australia.[43]

In 1905, a significant new manufacturer entered the market when R. Hornsby & Sons acquired the Stockport Gas Engine Works of J.E.H. Andrew & Co. Originally founded as a small blacksmithing shop at Grantham, Lincolnshire, the firm changed its name to Richard Hornsby & Sons in 1828 and began developing into a specialist manufacture of ploughs and agricultural implements. By the 1840s Hornsby were also producing portable steam engines and threshing machines and a decade later had established a thriving export trade to Victoria selling portable and stationary steam engines, boilers, mining machinery, farm implements and harvesting machinery. In the early 1880s they became one of the first British manufacturer to establish their own branch offices and showrooms in Melbourne and Sydney. In 1891, R. Hornsby & Sons became the first major British steam engine manufacture to acknowledge the turning tide and invest in the large-scale manufacture of internal combustion engines after signing a licensing agreement with Herbert Akroyd Stuart, inventor of the vaporising hot-bulb engine. Large numbers of the Hornsby-Akroyd oil engine were sold through the Melbourne branch of R. Hornsby & Sons from 1893, with some 5,000 at work throughout Australia by 1910.[44]

After taking over the Stockport Gas Engine Works, Hornsby extensively redesigned all gas engine models produced and began aggressively marketing the improved "Hornsby-Stockport" gas engines and suction gas producers from mid-1906. They had soon captured a substantial share of the Australian market for larger gas engines and by 1911 had over 400 Hornsby gas engines and suction gas plants, with a combined capacity of 20,000 BHP, at work throughout Australia. In 1918, R. Hornsby & Sons Ltd merged with another Lincolnshire engine builder Ruston, Proctor & Co Ltd, forming Ruston Hornsby Ltd. Production of gas engines continued at the Stockport plant until 1932.[45]

7. GAS ENGINES IN THE ELECTRIC POWER SUPPLY INDUSTRY

In 1896, the Victorian Government passed legislation giving municipal councils throughout Victoria the right to establish electric power supplies for both public and private use within their local government area. Councils were required to apply for approval to install an electricity supply through an order-in-council, an could elect to either establish the service themselves or sign an agreement with a private company to establish and operate the service on their behalf. Most councils, particularly in rural Victoria were slow to respond. Many of the larger towns by this time enjoyed an established town gas supply which adequately provided for the needs of public street lighting and home lighting. There was little incentive to commit to a major capital investment for what many saw as simply the duplication of an existing service.

By 1905, while much of Melbourne enjoyed an extensive reticulated electricity supply, provided by two central power stations run by the Melbourne City Council and Melbourne Electric Supply Company, only five regional towns had a public electric power supply – Nhill (from 1891), Ballarat and Bendigo (from 1896), and Inglewood (from 1905).[46] All these supplies were provided by steam-powered generating plant, but steam-power was relatively expensive install and operate, particularly for smaller towns with only a limited initial demand for power.

The introduction of suction gas engine technology at this time would provide a major stimulus for rural power supply offering a significantly cheaper alternative to steam power. Over the next decade up to the outbreak of the First World War, 59 further regional towns inaugurated local electricity supplies and all but two of these either wholly or in part used suction gas engines to drive their generators. Wonthaggi relied on a steam-powered electricity supply from the Victorian Railways State Coal Mines, while Leongatha drew electricity from the local butter factory's steam power plant.[47]

A survey of the equipment installed has shown that R. Hornsby & Co suction gas engines were by far the most predominant source of motive power, with 47 units totalling 2,926 horsepower installed in 39 power stations – representing 69% of all suction gas engines and 59% of overall horsepower installed by 1915. In the initial years the trend was even more notable, with Hornsby's claiming in their publicity brochures to have supplied 81% of the 22 suction gas engines installed for electric lighting in country Victorian towns by 1911.

Tangyes Ltd were the next most prominent with 13 engines installed in 9 power stations by 1915 – representing 17-18% of both the overall number of engines and horsepower installed. Other brands represented were Kynoch Limited, of Birmingham (6 engines – 8%),Hindleyand Gardner (both 3 engines – 4%), Premier (2 engines – 3%), Crossleys Ltd and Robson (both 1 engine – 1%). Engine sizes installed ranged from 16 to 108 BHP, with the average being 65 BHP. (Table 1)

1905-15	No Estb	No Units	Total HP	No Estb	No Units	HP
Hornsby	39	47	2,926	71%	62%	59%
Crossley	1	1	65	2%	1%	1%
Gardner	2	3	228	4%	4%	5%
Hindley	2	3	250	4%	4%	5%
Kynoch	4	6	376	7%	8%	8%
Premier	1	2	152	2%	3%	3%
Robson	1	1	65	2%	1%	1%
Tangye	9	13	870	16%	17%	18%
Total	55	76	4,932	-	100%	100%

Table 1. *Summary of Suction Gas Engines Installed in Victorian Country Power Stations, 1905-15.*

Hamilton were the first Victorian country town to install a gas-engine power supply, with the Hamilton Electric Supply Co Ltd installing a 50 horsepower Hornsby suction gas engine and producer in December 1905. By 1912 they had installed a second Hornsby gas engine of 100 horsepower and another of the same size again would be installed by 1920. Some councils sought tenders for both steam and suction gas powered plant, such as the Shire of Hampden who advertised for the "Supply and erection of High Speed Steam Engine and Boiler, &c" or "Suction Gas Plant and Gas Engine" for Electric Light Works at both Camperdown and Terang in July 1908. Within a few years, however, enough experience had been gained of running and installation costs for councils to directly specify suction gas plant.[48]

About half of the country electricity supplies established during this period were funded both private power supply companies on behalf of municipal councils or drawn from a local industry such as a dairy factory or flourmill. The remainder were directly funded and operated by the councils themselves. Most installations were initially similar, consisting of a single 50-80 horsepower gas engine with a flat-belt driven dynamo or generator supplying direct-current power at via a 2-wire or 3-wire distribution system at around 230 or 460/230 volts. Aside from municipal street lighting (usually by incandescent lamps), power was provided to private homes for lighting and sometimes to local industries for lighting or motive power. It was not until the 1920s that most households began installing other electric appliances such as stoves, heaters, hot water units and toasters. During the early years most municipal power stations only operated during daylight hours, with a bank of large accumulators or lead-acid batteries in glass tanks being provided to supply current overnight or whenever the plant was shut down for maintenance or repairs. Capital expenditure ranged from around £3,000 to £11,000 depending on the size of installation, with most of the funds spent on generating and distribution equipment. In most cases the powerhouse itself was little more than a corrugated-iron clad timber-framed shed.[49]

As demand for electricity grew, a second or third engine and generator was often installed. By 1920, reliance on storage batteries for overnight supply and peak demand was falling out of favour due to maintenance costs and limited service life. Instead an additional smaller auxiliary engine and generator was often installed after experience showed that a suction gas engine on light load could be left to run unattended for 4-6 hours overnight if a larger capacity gas producer holding adequate fuel was available.

Industry	Installations	Engines	Total BHP	Avg BHP	% All Engines	% Total BHP
Breweries	5	5	478	95.6	4%	6%
Brick & Pottery Works	5	5	499	99.8	4%	6%
Chaffcutting Works	4	4	116	29	3%	1%
Clothing Factor-ies	1	1	66	66	1%	1%
Electricity Sup-ply	32	36	2,266	62.9	26%	26%
Engineering	10	12	468	39	9%	5%
Flock Manufac-turing	1	1	100	100	1%	1%
Flour Milling	8	8	482	60.3	6%	6%
Ham & Bacon Curing	4	5	412	82.4	4%	5%
Mining	12	12	702	58.5	9%	8%
Miscellaneous Works	2	2	94	47	1%	1%
Printing Works	1	1	28	28	1%	0%
Pumping & Irrig-ation Works	6	7	261	37.3	5%	3%
Refrigeration	25	31	2361	76.2	23%	27%
Sawmilling	2	2	67	33.5	1%	1%
Tanneries	2	2	128	64	1%	1%
Woodworking, Coachbuilding, &c	3	3	78	26	2%	1%
Totals	**123**	**137**	**8607**	**63**	**100 %**	**100 %**

Table 2. *Summary of Suction Gas Engines Sold by R. Hornsby & Sons in Victoria, 1905-1913.*
Source: Ruston-Hornsby Order Books, Museum Victoria

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8. GAS ENGINES IN OTHER RURAL INDUSTRIES

By 1915, gas engines installed in country power stations represented two-thirds of the combined horsepower of all gases engines use manufacturing works outside Melbourne, however, suction gas engines and gas producers also found a strong demand in other rural industries. Although no overall figures are available on the numbers of gas engines used in non-manufacturing industries like mining and pumping for town water supplies and irrigation, some indication of their importance to other rural industries has been gained through an analysis of order books from the former Melbourne agency of Ruston Hornsby held in the collections of Museum Victoria.

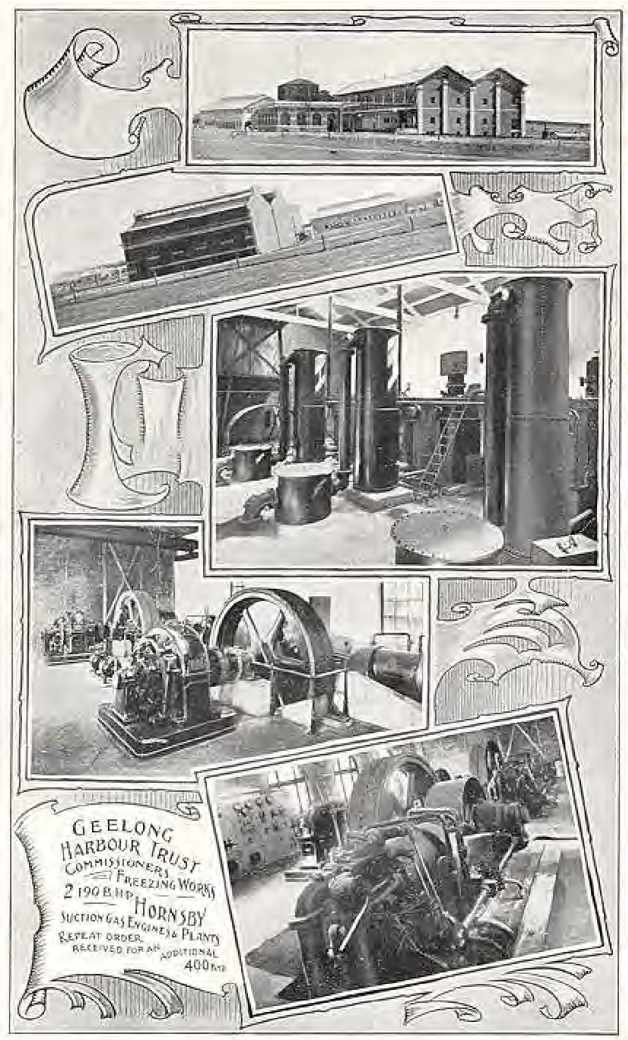

Figure 10: *R. Hornsby & Sons Suction Gas Plant at the Geelong Harbour Trust Freezing Works. Powering refrigeration plant for country meatworks, dairy factories and fruit coolstores represented almost a quarter of all Hornsby suction gas sales up to 1915.*
Source: Ruston-Hornsby Collection, Museum Victoria

9. CONCLUSIONS

Although gas engines never provided the principal source of motive power for Victorian industry, their introduction and use from the 1870s provided an important transition between steam technology and the later introduction of liquid-fuelled internal combustion engines and electric motors, which would become the principle source of industrial power in the 20th century.

Gas engines initially provided a cheap and effective source of mechanical power factories and workshops with smaller power requirements and played key role in the early mechanisation of several industries such as printing, clothing manufacture and boot & shoe making. They also provided a basis of local engineering skills and manufacturing expertise that would subsequently be developed into the large-scale manufacture of internal combustion engines in Victoria.

By 1905, the gas engine had entered the second era of its development and impact on Victoria. As the demand for smaller gas engines in inner city and suburban workshops declined the introduction of suction gas producers made the use of large gas engines more cost effective and the technology had a new lease of life providing versatile and low cost power for a variety of rural industries including in particular rural electricity supplies, water pumping, refrigeration and mining. For a quarter of a century the suction gas engine was the cheapest of all industrial power sources with an ability to throb away tirelessly for hours on end on literally the wiff or a half bag of coke or a few shovels full of charcoal.

It is ironic that as their era as an industrial workhorse drew to a close in the late 1930s, a new use for gas producers and gas-powered internal combustion engines was being discovered as a low-cost power source for running road vehicles and tractors during the petrol rationing of the Second World War.

10. ACKNOWLEDGMENTS

This assistance of David Crotty, Colin Heggen, Rohan Lamb, Miles Pierce and David Yandell in contributing ideas and information of the my research in complying this paper is gratefully acknowledged.

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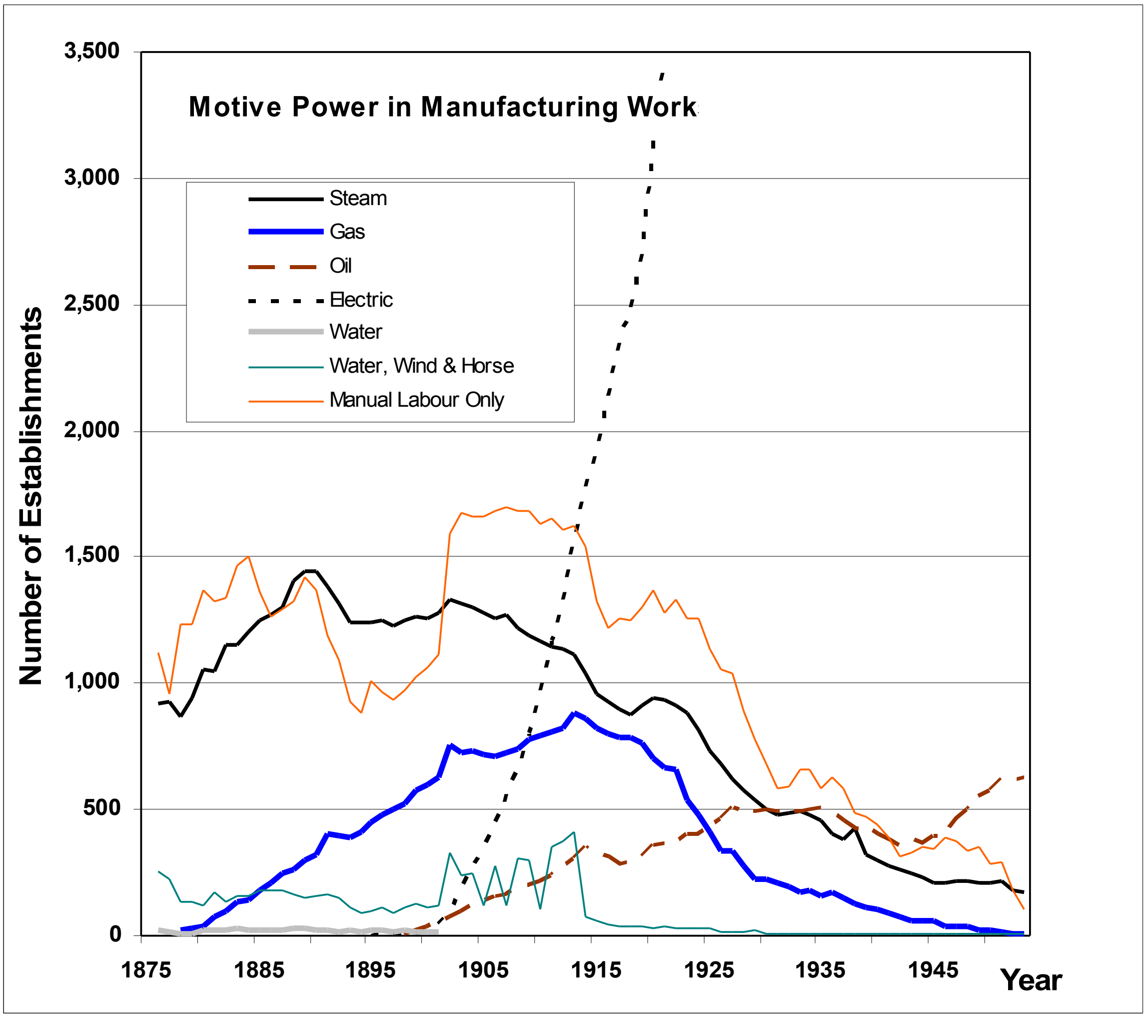
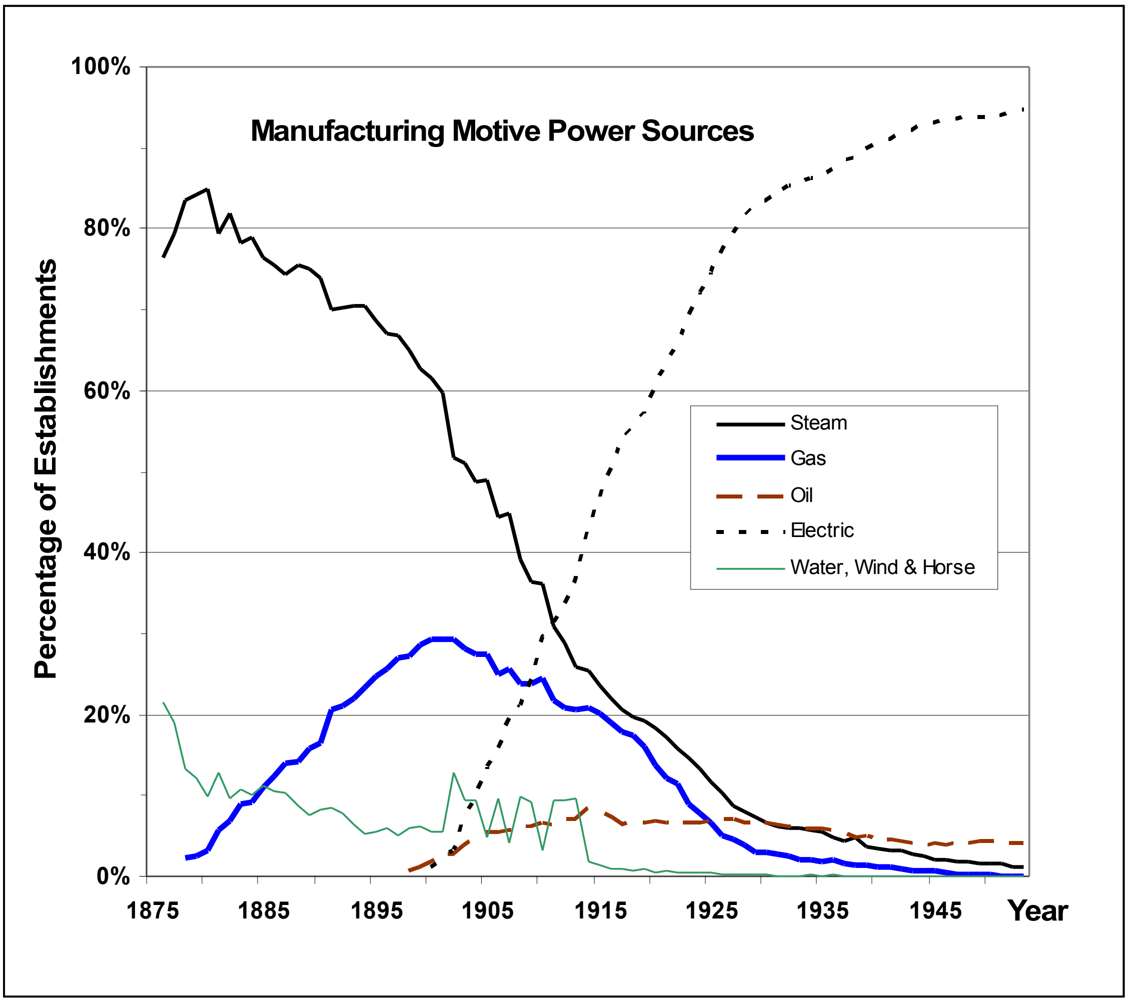
12. APPENDICES

Appendix A: Sources of Motive Power Used in Victorian Manufacturing Works, 1875-1955
Source: *Victorian Statistical Regisgters, 1875-1915; Victorian Year Books, 1901-1955*



Appendix B: Proportion of Mechanically-Powered Victorian Manufacturing Works Using Power Sources, 1875-1955

Source: *Victorian Statistical Registers, 1875-1915; Victorian Year Books, 1901-1955*



Refrigeration: underpinning the New Zealand economy for over 125 years

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SUMMARY: *In 1882 the first refrigerated meat left New Zealand for London, the pioneering use of a technology that was to transform the New Zealand economy. Animals were no longer grown for wool only, and the wealth of the nation developed rapidly. From 1882 until as recently as the early 1990s refrigerated food has returned at least 30% of New Zealand's export income. Whilst much of the equipment has been imported, expertise in the application of refrigeration was developed in New Zealand. This paper describes some of the key engineering and technology developments through the history of the refrigerated food trade in this country. Examples include development of carcass freezers, boneless beef carton freezers, and systems development in the horticultural sector. It also identifies some of the iconic equipment systems used in the New Zealand industry, some of which have given reliable service for a century.*

1. FROM SUBSISTENCE TO PROSPERITY

In 1982, in a plenary presentation to the first conference of the International Institute of Refrigeration held in New Zealand (on the centenary of the first frozen meat trade), Professor Dick Earle wrote "Without refrigeration New Zealand would be a poor country in the South Pacific. Refrigeration gave New Zealand the opportunity to develop an extensive export economy, which has made possible a high standard of living for the population and the opportunity to be a world leader in social development. Refrigeration was, and continues to be, of utmost importance to the New Zealand economy and to the New Zealand people. It turned the blessing of a good climate for pastoral farming into a major economic resource" [1]. He went on to point out that New Zealand had the largest refrigerated storage volume per capita of any country, and that in 1980 36% of New Zealand's export earnings were from refrigerated food. For over a century refrigerated food was at least one-third of New Zealand's export earnings.

The earliest products were frozen meat, butter and cheese. There was considerable growth in animal numbers through the first half of the twentieth century, and then following World War II there were real boom times as New Zealand reached third place in the overall wealth rankings for nations. Our traditional trade partners (especially the United Kingdom) were short of food, and our part of the British Empire could supply it! With the ability to generate revenue from both wool and meat, the incentives to break in new land for sheep farming were considerable and large-scale land clearance occurred right through to the second half of the 20th century.

Somewhere in the 1970s or 1980s the peak importance of refrigerated food as an economic driver was reached. Sheep numbers peaked at about 70 million (they are now about half that number), and the dairy industry started to change with greater emphasis on protein-based rather than fat-based products. These declines were masked for a time through considerable growth of the beef industry and then venison, the fishing industry (following the declaration of a 200 mile economic exclusion zone), and the development of the apple and then the kiwifruit industries. Some of the newer food export industries (like the wine industry) and the food ingredient business of the dairy industry use considerable amounts of refrigeration, but their products leave our shores unrefrigerated.

In the 21st century, New Zealand has settled back to about 15th to 20th place in the world wealth rankings – about where we were prior to World War II. Looking at the profile of the food export trade in 2009, meat (lamb, mutton, beef and venison) is still very important, but much of this leaves chilled rather than frozen. Considerable volumes of apples and kiwifruit are still exported, along with small amounts of other fruit and vegetables. There is a considerable tonnage of frozen fish, and still butter and cheese (although much more of the milk fat ends up in whole milk powder than previously). There are also refrigerated food manufacturers for local consumption – including frozen vegetables, bakery products, ice cream and poultry. The service roles of refrigeration in the dairy, brewing and wine industries is significant.

We have a small manufacturing base for certain types of equipment (although perhaps less so than in the boom times), and like most countries have expanded the use of commercial air conditioning. However, the bulk of the equipment we now use is imported. The New Zealand refrigeration story is not so much about the equipment we used to make the "cold", but rather how we applied the "cold" to food products.

2. EARLY MEAT INDUSTRY REFRIGERATION

The first refrigeration was entirely on board ship. Sheep carcases were frozen using air cycle machines on the *Dunedin* (at Port Chalmers) which blew the cold air stream directly over the carcasses. About 300 carcasses could be frozen at once. A total of 4,909 carcasses made the first voyage so the loading and freezing process took some days, the ship eventually setting sail on 15 February 1882.

There was clearly economic advantage in the freezing process being carried out on land, so that only storage was required on board ship at sea. A number of small freezing works were established in the three decades from 1882. In these plants, slaughtered sheep were moved into freezing rooms, and then dropped down a chute into cold stores below. At a later time they could be loaded out and transported to the port.

The freezing rooms typically had bare pipe grids in the ceiling over the top of rails on which sheep carcasses (or quarters of beef) hung (Figure 1). Natural convection heat transfer occurred (typically with air temperatures of the order of -15ºC), with freezing often taking three days.

Figure 1: Carcass freezing room reliant on natural convection heat transfer to bare pipe evaporator overhead.

Figure 2: Cold store cooled by overhead bare pipe evaporator.

Undoubtedly there was a fair degree of experimentation with different cooling systems. The open air cycle refrigeration was quickly replaced by carbon dioxide closed systems, and then by ammonia which became the dominant refrigerant of the 20th century New Zealand industrial food refrigeration industry. Some early systems cooled calcium chloride brine which circulated in the pipes, but eventually ammonia was used directly in the pipe grids.

Immediately following World War I, difficulties in procuring shipping led to the failure of a number of small meat companies, and there was a consolidation of meat freezing plants and companies – both local farmer cooperative companies and major United Kingdom companies emerged as multiple plant owners. As the scale increased, ammonia refrigeration became the dominant technology. However, the freezing rooms and cold stores (Figure 2) changed little in function.

After World War II systematic developments occurred leading to two notable technologies – the air-blast carcass freezer, and the carton freezer.

3. AIR-BLAST CARCASS FREEZING

3.1 The Dominance of Efficiency

As the size of meat plants grew (by the 1980s there were plants processing 25,000 animals per day), the demand for efficiency was strong. Commencing in the late 1940s, considerable development work was undertaken towards air-blast freezers for lamb and sheep carcasses. The concept was to use finned surface evaporators and large scale fans to cool and then direct the refrigerated air over the carcasses. A freezing time of less than 16 hours could be achieved, allowing overnight turnaround on the freezing rooms – perfect for mass production. There was also the potential to reduce product weight loss and to lift suction pressures, saving energy. Ellis Hardie Syminton Ltd patented the A189 air-blast freezer in about 1950 – it allowed for multiple air re-cooling between groups of carcasses. The local refrigeration engineering company worked with the development engineering group of Thomas Borthwick & Sons Ltd (a major plant owner) at the development laboratory of the latter at the Waingawa works near Masterton. Over the next 20-30 years, the air-blast freezer became universal in the New Zealand industry. Several variations were developed (Figures 3,4), and over time horizontal air flow was phased out in favour of vertical air flow as the latter gave better air distribution. Single storey was partly replaced by multi-storey (up to six storeys) in some of the larger plants in the 1980s. There was also a move from batch to continuous production.

There was also considerable automation – the batch rooms required labour to move carcasses in and out, the continuous freezers moved gantries along the freezer with one such gantry unloading and another loading at any time. In short, the industry applied all the principles of mass production.

Figure 3: Cross-flow air-blast carcass freezer

Figure 4: Typical modern air-blast carcass freezer

By the 1980s, energy efficiency became an important parameter, and means to minimise energy costs were explored. One of the most advanced systems was a predictive control system run on a PDP8 computer at the Pareora works of the then Canterbury Frozen Meat Company. As gantries of carcasses passed each fan zone, the computer determined the lowest possible velocity that would just freeze those carcasses before freezer exit – small carcasses passing would mean a drop in fan speed in the zone. Given the power law relationship of fan speed and power use, plus the reduced refrigeration load when the fans were slowed, the energy savings were considerable.

3.2 From Efficiency to Meat Quality

Although it was not realised at the time, the move to faster freezing times, and a desire to cool as rapidly after slaughter as possible to minimise microbial risks, led the meat industry to freeze meat carcasses too quickly – resulting in toughened product. Commencing in the 1970s, research at the Meat Industry Research Institute of New Zealand highlighted the need to control the temperature/time regime carefully, which was subsequently modified by the introduction of electrical stimulation. This new knowledge led initially to at least a proportion of the kill being held in chiller conditions for a period of time prior to freezing, and more latterly to a carefully controlled air temperature/air velocity regime. It became necessary to also differentiate on the basis of animal size lest small carcasses be allowed to cool too rapidly.

These needs led to significant advances in control systems to adapt the carcass blast freezers to the new requirements. Fan speed controls to slow air velocity now had dual benefits – both improved product quality, and reduced energy costs.

By the 1970s, improvements in the dressing of product, and improvements in both packaging and air temperature control meant it was possible to export chilled product by surface freight systems. This, plus the general reduction in the number of lamb carcasses per year, has led to a significant shift away from the air-blast freezer as the dominant technology. Chillers for both carcasses and boned cuts, sophisticated packaging systems and closely controlled chill storage have become more important.

4. THE CARTON FREEZER

Prior to the 1950s the beef trade had been dominated by quarter beef. The emergence of the hamburger in the United States of America opened up a new product line – frozen boneless beef suitable to be processed directly. The New Zealand industry responded. The process involved an overnight chill of beef sides to 10ºC and then boning out of the sides to fill cartons to be frozen.

Working with Ellis Hardie Syminton Ltd who did the refrigeration, Bill Freeman of the Cooperative Wholesale Society designed and constructed the world's first continuous carton freezer for cartons of beef at the company's Longburn freezing works near Palmerston North. The completion was during the 1959/60 processing season. Moveable racks were loaded at the entry, and then pushed progressively along to the other end of the freezer. They then dropped down to a second level and returned out to the entry end (Figure 5). Air was directed in cross flow across the tunnel – via large-scale fans. The carton held 27.2kg and was typically about 150mm thick. Solid wall fiberite was chosen to minimise insulation, and by using air temperatures as low as -40ºC and air velocities of the order of 3m/s a 24-hour freezing time was possible. Some companies preferred a higher air temperature and a 48-hour turnaround.

The range of cartons is much more diverse these days so some companies have chosen to return to smaller batch freezing rooms, sorting cartons by size and shape. There have been some variants of the continuous carton freezer, but the basic design is still in use in many countries 50 years later. This basic design which has endured to this day is a testament to the early engineering success of Bill Freeman.

Figure 5: Load-in and load-out area of a continuous carton freezer – cartons are placed on the racks and transported along the freezer (with air cross-flow) to return on the upper level.

5. METHODS OF REFRIGERATED ROOM CONSTRUCTION

The early insulation systems tended to fail eventually through vapour barrier penetration, and insulants like cork were not that effective. By the 1960s the expanded polystyrene sandwich panel and sprayed polyurethane had become the dominant insulants. Forced draught cooling units became the norm. New refrigerated rooms had to be added to the extremities of plants which in turn led to long pipe runs from centralised plant rooms, which created the need of a new set of expertise in controlling the systems (see below).

6. THE MEAT WORKS ENGINE ROOM

Powering the very large refrigeration systems was no small order. At the peak size of the industry there were plants generating more than 5MW of cooling effect, and because the load varied significantly during the working day, very flexible plant rooms were required.

As stated earlier, ammonia rapidly became the dominant refrigerant. Much of the first large scale equipment installed in the early 20th century is still capable of operating to this day, but as capacity was increased new technologies were adopted. The following compression equipment was widely applied:

Large horizontal-acting compressors circa 1910-1920 – these were low speed and often only a single cylinder (which may have been double acting). Early such compressors were driven by steam engine, but when electric motors were installed there was a need for large flywheels to balance the load (Figure 6). Hall and Haslam were common brands, and a few such machines are still in service.

Multi-cylinder vertical compressors – these were typically installed between the two World Wars – slightly faster and generally with an enclosed crankcase (Figure 7). Again, many (including Halls and Sternes) were still in action fifty years later. Some of these were compound compressors accomplishing two compression stages in different cylinders in the same machine.

Figure 6: A horizontal open compressor with flywheel.

Figure 7: A typical vertical cylinder compressor with enclosed crankcase.

Figure 8: A typical Vee block compressor used both within and outside the meat industry.

Vee block reciprocating compressors – typically installed after World War II. These were electrically driven and used largely as the high stage on multiple stage compression systems. The most common were Hall 5x4 and 7x5.5inch machines, driven by 125HP or 250HP motors respectively (Figure 8).

Figure 9: A typical rotary vane booster compressor.

Figure 10: A relatively early model twin screw compressor

Rotary vane compressors – typically used as boosters on multi-stage systems, after World War II – the Fuller brand was common (Figure 9).

Twin screw compressors – installation commenced in the 1970s (mainly Howden machines in the early days), and these machines were widely applied thereafter (Figure 10). These machines could be very large – up to 1000HP required to drive the largest. The monoscrew compressor never really took off in New Zealand.

Condensers were often locally made – early systems used evaporative cooling reliant on natural air flow over large-scale pipe grids, but with a water spray over the top. The next stage was the wide-scale use of both horizontal and vertical shell and tube condensers, sometimes with evaporative cooling systems to re-cool the cooling water (Figure 11). Whereas evaporative condensers were widely applied in Australia at the same time, in New Zealand the plentiful water supply led to a different approach. Only in the last 20-30 years have evaporative condensers (Figure 12), plate heat exchangers and imported water cooling towers been widely applied.

Perhaps the major New Zealand contribution to engine room engineering was in pump circulation of ammonia. Due to the very large scale of meat plants, very large

Figure 11: Typical vertical shell and tube condensers used in the meat industry.

Figure 12: An evaporative condenser in service at a meat freezing plant.

pipe runs were needed, and the volumes of refrigerant were substantial. Commencing prior to World War II, New Zealand refrigeration companies like Ellis Hardie Syminton and then later Refrigeration Engineering Ltd developed the expertise to design, build and then control large-scale pump circulation systems. Low-pressure liquid accumulators (called "pots") were placed in the engine room, and from these liquid was pumped out to a variety of applications. The return stream was separated in the pot upon its return and the vapour drawn off to compression. Given that the loads were highly variable there was a considerable control problem – the plant operators had the expertise to ensure major liquid flood backs did not occur. Typically there were two to four such pots in a large meat works, although very complex plants could have more.

7. THE DAIRY INDUSTRY

The early dairy industry was characterised by a large number of small local factories. Farmers would separate cream from skim milk on farm and take the cream by horse and cart to the factory. There, the initial product was butter, but cheese was also important. Farmers were paid for many decades on the basis of the fat supplied, ignoring the protein component of the milk. With the development of refrigeration and mechanised transport bulk milk collection was able to commence. Stainless steel dairy vats with refrigerated pads were made locally and milk was cooled on farm, to be collected daily. In contrast to the use of natural refrigerants in the meat industry, this on-farm development applied synthetic refrigerants (CFCs) in the main. Consequently, the number of dairy factories rapidly reduced.

By the 1980s the increasing efficiency of the on-farm systems and improvement in hygiene meant that less frequent tanker collections were possible. With mechanisation the average dairy herd size rose rapidly, and the age of the mega-factory supplied over very long distances was born. This is the dairy industry New Zealand has today.

On-plant there is also a need for cooling – large quantities of chilled water are used and direct refrigeration is used in continuous butter makers as well. There has always been refrigerated servicing of cheese making e.g. curing rooms. Mechanical vapour recompression has become the norm in evaporation of milk towards milk powder.

In terms of New Zealand innovation, the local design and manufacture of the refrigerated dairy vats was significant. There was also some New Zealand-designed equipment for cheese making. However, the other technologies, including the cold stores for butter and cheese, were relatively standard.

8. THE FRUIT INDUSTRY

The export apple industry started to gain scale in the 1970s and rapidly expanded in the two decades thereafter. The building technology evolved into relatively simple but massive cool stores, which had pre-cooling areas in which the initial field heat could be withdrawn from the product. Where New Zealand was innovative was in the control of relative humidity of the air. As the fruit was unwrapped it was desirable to minimise water loss, but a high relative humidity would reduce the strength of the fiberite cartons. Through research, process understanding was developed to enable high relative humidity to be obtained, as well as ensuring tight temperature control. This lengthened the storage life and enabled transportation to distant markets.

New Zealand also took up controlled atmosphere storage, but made limited use of modified atmosphere packs. It developed expertise in the mathematical modelling of the heat and mass transfer processes which could be applied to ensure that the local relative humidity established in the pack around the fruit was controlled to the optimum level by setting the perforation size and number.

From the 1980s the kiwifruit industry developed in parallel. The scale of the storage facilities was smaller initially, but the industry evolved in scale and technology to parallel the apple industry. The know-how for using temperature, packaging and gas composition to maximise product quality has been central to the success of these industries.

There is also a small frozen vegetable industry – potato products, peas, beans and corn. This has always tended to use imported freezing technology, but ammonia refrigeration.

9. OTHER INDUSTRIES

The other notable food refrigeration export industry was the fishing industry. This now has a high proportion of off-shore processing on factory ships. The on-shore technology tended to draw on the experiences from the meat industry. Hence there is little of engineering heritage significance in the industry.

Likewise, the brewing, ice cream, bakery products, wine making, confectionary and poultry industries also use significant amounts of refrigeration, but in their history there is nothing particular to New Zealand engineering heritage.

New Zealand has had commercial display cabinet manufacturing (including for export) over several decades but on a modest scale. McAlpine Industries (later McAlpine Hussman) was the initial major player, but more recently Skope Industries has also become a significant-size manufacturer. There has been a single manufacturer of domestic equipment (Fisher and Paykel) for the last 70 years, initially manufacturing under licence, but now using its own designs.

10. NEW ZEALAND CONTRIBUTION TO RESEARCH AND DEVELOPMENT

By the 1960s, New Zealand started to publicise its research into refrigeration on the national stage. The main contributors were the Meat Industry Research Institute and Massey University, both reliant on Professor Dick Earle to pioneer their initiatives.

The best-known research that established New Zealand's reputation, and forms part of our refrigeration engineering heritage, was the development of highly sophisticated mathematical models of food refrigeration processes and systems, particularly as applied for food freezing and chilling. We led the world on development of methods to predict freezing times, and then the modelling of simultaneous heat and mass transfer in the horticultural industry. We also did considerable pioneering work on measurement and later modelling of overall refrigeration system performance, particularly looking to improve process control and energy efficiency. This was not a small undertaking as several megawatts of refrigeration effect was not uncommon on large freezing plants. New Zealand-developed software to apply the models was used in a number of countries.

Heat pump technology has also been developed by New Zealand researchers. Through the University of Otago a domestic hot water heating system, and through Massey University a trans-critical carbon dioxide system were developed, both in the last decade.

By the 1970s, New Zealand had started to become active in the International Institute of Refrigeration (IIR) – an intergovernmental organisation to promote the wide application of refrigeration. New Zealand hosted major international research conferences in 1982, 1993 and 2006, and co-hosted the four-yearly International Congress of Refrigeration with Australia in Sydney in 1999, a massive undertaking with over 500 technical papers presented.

A local learned society (initially the Institute of Refrigeration and Air Conditioning Engineers, but later to become IRHACE through the addition of "Heating" to the name) was also established. This tended to gather the refrigeration engineers operating with synthetic refrigerants more than those applying ammonia in its early life, but by the 1990s it was operating across the whole industry and there were close links with the IIR and local research groups. IRHACE and the New Zealand National Committee of the IIR now act as the hubs for distributing new knowledge in the industrial food refrigeration sector.

11. SOME PERSONAL MEMORIES

My own memories commenced in 1974 when I took up my first holiday job at a meat plant – it had a horizontal-acting Haslam compressor operating on a flywheel rope drive system. I had considerable involvement from then until the turn of the century.

Failure of insulation systems was a major problem I experienced at first hand. Over many decades ice build-up in the underfloor region would occur. In most parts of New Zealand the permafrost layer underneath was of the order of 10-12m, so the floor in the middle of an old meat works cold store could have a heave of up to one metre in the middle – I recall entering many such stores. Fortunately (I think) I never came across one of the feared freezer rats – rats that had adapted and lived in the central hollow of a meat carcass in cold store – reputedly, if disturbed, their eyes could not cope with bright light and they could be quite dangerous.

I recall doing a refrigeration survey at the Ocean Beach freezing works at Bluff – its condensers were cooled by sea water, trapped by a one-way gate which closed off at high tide, entrapping sufficient coolant until the next high tide. Sea life getting into the water pumps was an ongoing issue.

Then there were the tough shift engineers who manned and controlled the plants. Some of their control expertise was brilliant – there was an old saying – "if you had 10lb by 10 at night you would be alright" – if the suction pressure at 10pm had dropped to 10lb/sq inch then the meat would be frozen by morning – a rule of thumb that meant the engineers could operate a variable set point control system. Their replacement by early automatic control systems with fixed set points dramatically increased (and even doubled) the energy required to freeze meat until the control systems could be improved.

Whilst the memories are strong for me, too much of the story of the technology development remains untold in New Zealand. I hope this paper goes some small way to tell some of the important stories.

12. CONCLUSIONS

New Zealand has a rich heritage of innovation on refrigeration engineering as it pertains to the frozen and chilled food industry. The major innovations are in process technology rather than in equipment systems, and this heritage is difficult to preserve in the form of artefacts.

This paper sets out some of the important advances that form part of our refrigeration engineering heritage. Without those advances New Zealand may have taken a much less prosperous journey through its economic development over the last 125+ years.

13. REFERENCE

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14. ACKNOWLEDGEMENTS

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3rd Australasian Engineering Heritage Conference 2009

Does the Engineering Heritage Matter?

Sir Neil Cossons, UK

SUMMARY: *In this illustrated lecture Neil Cossons sets out the issues surrounding the conservation of the engineering heritage with examples of some of the achievements, and dilemmas, in this important field. He will emphasise the importance of the engineering heritage as an integral part of the past that we wish to take into the future and the crucial need to engage with the public and the wider heritage movement. The following is a summary text of his lecture.*

To engineer is human. Our capacity to make and use tools is perhaps the decisively distinguishing feature of our species, marking in the transitions from stone, to bronze, to iron the early epochs in human history.

Today, nothing has changed. It is still our capacity to affirm some degree of mastery over our habitat and advance our wellbeing that characterises us, at least in the material sense. But in the last three hundred years or so these skills have become not only more specialised but professionalised too. These are the people we call engineers. In the words of Samuel Smiles (1812-1904) in his *Lives of the Engineers*, published in 1862, 'Our engineers may be regarded as the makers of modern civilisation'. 'Are not the men who made the motive power of the country, and immensely increased its productive strength, the men above all others who … make the country what it is?'[1] Smiles of course saw engineers as the heroes of his age. Today, to the public at large, they can be invisible and profoundly misunderstood. But, their role has never been more important.

Engineering as we know it today is to a great extent the product of the age of industry which, with its origins in early eighteenth century Europe, has transformed the lives of us all. In Britain, the first industrial nation, what came to be called the Industrial Revolution represented a transformation in society, the economy and the landscape, unprecedented in its impact and consequences. Today, in much of the old industrial world the age of industry is now past; but, of course, this European decline is a geographically relative term. Elsewhere, in India or China or Brazil, industrialisation in its contemporary manifestation is being actively advanced as the path from rural poverty to some new form of prosperity. As a result the epicentre of the global economy is shifting radically. At the heart of these cataclysmic changes is the engineer.

It is worth reminding ourselves that it has been industrial and technological change that has been one of the primary causes, for good or ill, of these great global upheavals. As in the eighteenth century, industrialisation – and now of course de-industrialisation - has been the most significant of the various forces affecting societies and economies across the globe. And, if the engineer can be credited with being one of the essential creative forces in the making of the modern world during that heroic age of engineering in the nineteenth century, the same is undoubtedly so today. It is also of course to the engineer that we are now turning to find solutions to the issues of the contemporary world; of global warming and climate change, developing new and sustainable sources of energy, and enabling us to use that energy with ever greater effectiveness through improved means of conservation.

All this reinforces the case for recognising the importance of the engineer over time. Engineering has a distinguished and distinctive history but it is the heritage – the material evidence – of engineering that represents the most palpable and visible symbol of the engineer's past achievements and continuing contribution to humanity.

I spoke just now of the heroic age of engineering, of that period when the sentiments of Samuel Smiles echoed the sentiments of the nation, when the names of engineers were familiar to everyone, and when engineers were lionised as the giants of their age. The names of today's engineers are no longer familiar to anyone, and yet their achievements are all around us. This is a reflection perhaps of one of the greatest and most paradoxical contributions of the engineer to our lives, to deliver such extraordinary qualities of reliability, efficiency and safety that the rest of us can take it for granted; that the planes fly, the phones work, the light goes on when we flick the switch, and great bridges and dams and viaducts do what they are supposed to do, unfailingly and invisibly. It is perhaps the ultimate and immutable irony that the fate of the engineer is to be the unseen hero in a world where the public's expectation – almost as a birthright - is to enjoy total dependability and of course of continuous improvement.

It is in this new environment, and in the context of the changing perceptions of the public towards this crucially important aspect of their history, that we contemplate the prospects for conservation of the engineering heritage. When industrial archaeology emerged in the middle years of the twentieth century there was a growing recognition – for which there was then a surprising and significant amount of popular public support - that the origins and subsequent evolution of industrialisation and of engineering – the two are not entirely synonymous - deserved recognition, that the material evidence was a legitimate and rewarding field of study, that some of that evidence was sufficiently emblematic of a vital and vivid past to justify retention, and that future generations might gain from it inspiration and understanding. Industrial archaeology struck a chord with a public who, perhaps for the first time, could see their own history, places that reflected their own lives and their own values, being taken into care for the future. In this respect industrial archaeological conservation and to an extent the engineering heritage was, if not unique, then certainly novel.

In today's world we cannot take those views for granted. The case for the engineering and industrial heritage is by no means self-evident, not to many engineers themselves, and certainly not to the public. The justifications are no longer obvious. In the old industrial world consciousness of the importance of the social and economic changes wrought by industrialisation, and first-hand knowledge and experience of industry and all it represented, is evaporating as generations change and the public experience of work, in the industrial sense of the term, fades. And with it have gone the powerful collective memories of those industrial communities. That is inevitable. If the years of industrial growth were characterised by rapid and fundamental change, so too the era of industrial decline has arrived with even greater speed and brought about equally cataclysmic social and economic change at a pace unimaginable even thirty years ago.

So if in this old world, the great age of industry has come and gone, as has the heroic age of engineering, it is to be expected that the values and meanings attaching to this inheritance will fade too. For this new public the industrial and engineering heritage and all it represents will be as distant, as alien, as incomprehensible, and on the face of it perhaps as irrelevant, as the remains of ancient Athens or Rome.

In 1953 the English author, L P Hartley (1896-1972), famously wrote: 'The past is a foreign country; they do things differently there'.[2] In the case of the industrial past and the engineering heritage we can expect that sentiment increasingly to become a truism. We should not be surprised. In this new world influencing public perception and public attitude will I suggest be at least as much a challenge as managing the physical remains themselves. Without public enthusiasm and public support we will not have an enduring engineering heritage. So, we need to re-articulate the significance of the engineering heritage to those for whom it has no immediate or obvious meaning. It will be a task we neglect at our peril.

In Britain the age of industry has defined us – and continues to define us - in more ways than we care to think. What we do is what we are. Work, once considered a curse, lies at the heart of our being, our identity, our self-esteem, our financial security. In an age where our prosperity derived from the output of mines, mills, factories and foundries, the value and meaning of work made some sort of sense. There was a simple clarity about what went in at one end, gained value as a result of work, and came out at the other. Profits were made, workers were paid. Today, men who once made steel now pump iron; people not only go out to work, they work out. Muscles are for decoration and magazine covers. In the modern post-industrial world we have to exercise our bodies because work no longer does that for us. But neither of course does it exhaust to the point of collapse, leave lungs destroyed by silicosis, or the lives of men and women terminated before their prime. That is a privilege reserved to those who are creating new industrial economies in the new industrial world.

So, if the heroic age of engineering and industry is now gone, what do we want of its remains? Do its vestiges and its memories matter, and if so to whom? Is this a history we wish to take forward with us, that future generations might gain from it some understanding and meaning? Or, can we let it go, relieved that the problem has quietly slipped away? Was it all too much to handle and the loss of its departing of no real consequence? Indeed, is this a chapter of history we might wish to consign, consciously and even enthusiastically, to oblivion? I think not.

Or, again, is this a history just for enthusiasts? Much of it is in the care of voluntary enthusiast groups whose energy and dynamism has preserved tracts of the engineering heritage that otherwise would be lost. Their contribution is outstanding. It should not be neglected, nor taken for granted. But, do they contribute to a wider public understanding of the importance of engineering or are they merely tolerated as mildly eccentric nostalgics who provide some casual entertainment, mainly for each other, at weekends or rallies? I think not.

So, where do we go from here? First, we need to assert that the engineering heritage is not a separate or alien heritage but part of the lives of us all. Second, engineers need to state clearly and unequivocally why it matters to anyone other than themselves. Is this a hobby for consenting adults in private, to which the public is admitted under sufferance, or is there some deeper and more inspirational meaning? Or, is it special pleading on behalf of engineers who, feeling unloved and unwanted, need to make a pitch for a place in the cultural firmament? And, third, if it does matter, does the preserved engineering heritage reinforce or degrade the value of engineering as a profession in the eyes of the public?

If today's engineers, as skilled professionals, carry out their trade in clinically clean environments, enjoy working conditions as good as anyone and better than most, does the engineering heritage that the public sees reinforce this image or paint a picture of a past we should be putting behind us? Are you, as engineers, comfortable with an engineering heritage inhabited, as one commentator put it, by 'a collection of old men in boiler suits, refugees from the wife or the washing up', and who tend to inhabit these places? Indeed can we have the one without the other? Is the engineering heritage already so marginalised in the eyes of the public, so totally dependent on its insiders who do things their way or not at all, that it is too late to command wider public respect and value? I think not.

Some of the causes may lie in the exclusive nature of the engineering community who, drawn together by education and professional standards ultimately find themselves unable to talk to ordinary mortals outside their own priesthood. Today, engineering, except in unusual cases, is a co-operative, social, team activity requiring long and intensive training and resulting in those on the inside sharing values and experiences, and a common culture and language, that excludes others. It would be contrary to human nature for such people not to regard those on the outside with a degree of disdain. It is a problem shared by many professionals – architects and lawyers come to mind - who, without regular reality checks from the outside world, will soon be seen as separate tribes whose professionalism may endow them with extraordinary qualities but whose language excludes. No wonder engineers can be found clumped together as like-minded souls, crying into their beer because nobody loves them.

So, let me attempt a few answers and pose a few more questions. First, I hope we can all agree that the engineering heritage is significant as a tangible historical record, the material evidence of an important aspect of our collective past, of which we are all a part. It deserves its place in our future, alongside everything else that we recognise and revere. Engineering is a part of our communal culture. Its heritage represents a crucial part of a bigger picture, defining identity, achievement, skill, and confirming humankind's extraordinary and ingenious capacity to overcome adversity.

Second, intelligently presented, its meanings and metaphors should strike a chord with every one of us. And that, surely, is the best reason for preserving it. Here is the clue, for the rest of the world, to what it is that engineers do. Celebrate the past, inspire the future, but most important of all let those on the outside see, feel and understand something of what it is that makes engineers tick.

In most countries that have protective legislation for the preservation of the heritage it is now common to designate bridges, factory chimneys, mills and factories, examples of civil or structural engineering virtuosity, as an integral part of the historic environment. That battle – certainly in Britain and throughout much of the developed world – is largely won. Thomas Telford's great suspension bridge across the Straits of Menai in North Wales must surely stand as one of the great works of art and engineering of all time. It enjoys not just legislative protection but universal esteem by the public. Telford, the first President of the Institution of Civil Engineers, who through his achievements helped to define the nineteenth century, more than any other established engineering as a profession. In 1819 Telford toured Scotland with Robert Southey, then poet laureate. Of the entrance to the Caledonian Canal, which they visited together, Southey wrote 'here we see the powers of nature brought to act upon a great scale, in subservience to the purposes of men'.[3] Telford and Southey enjoyed each other's company. The poet had a profound respect for the engineer. He was not the last to recognise the poetic in the achievements of engineers, nor the power of poetry to describe the glories of engineering.

Telford's roads, bridges, canals and harbours demonstrate clearly and powerfully the triumph of mankind over nature in the interests of creating a universal good. Most if not all of his surviving works are now accorded protection under the respective heritage legislation of England, Wales and Scotland and, of course, Sweden where his Gotha Canal is seen as a great national monument. Perhaps more importantly many are known, respected and sought out by an increasingly knowledgeable public. So too the work of the Stephensons and the Brunels, widely recognised as giants of their age.

But in one sense bridges and viaducts, aqueducts and flights of locks, are easy. Their visibility and not least their popularity and acceptance by the public guarantee them a place in our future. In a competition conducted by the BBC in 2006 to find the 'greatest Briton', to the surprise of many, Isambard Kingdom Brunel (1806-1853) came second. Only Winston Churchill gained more votes. The polymathic Brunel, designer of Clifton Suspension Bridge, the Great Western Railway, and three innovative steamships of which one, the ss *Great Britain*, is preserved in Bristol today, beat William Shakespeare, Charles Darwin, Nelson and Wellington, to name but four. As a result engineering and the engineering heritage gained an extraordinary boost. In this respect the past most certainly has contributed to the future. This is what I mean by bringing the engineering heritage to a wider audience. Special issues of postage stamps, names of streets, universities and research institutes, commemorative plaques on buildings, all can add to the universal lustre.

In this respect the monumental achievements of engineers are increasingly recognised.

More problematic are buildings – as opposed to great structures - that reflect engineering genius. It is a *sine qua non* that a building should be used, so for many industrial buildings their future is predicated on adaptive re-use, on finding some effective means of re-cycling them so that they can continue to make an economic contribution to society. Consider two examples.

In Shrewsbury stands the world's first iron-framed building, built in 1796/7 as a flax mill and innovative because it brought together for the first time cast-iron columns, supporting cast-iron beams which in turn supported floors on brick jack arches. In this way the building contained no combustible materials. It was the culmination of systematic research to make mills and warehouses fireproof and it set the pattern for the first half of the nineteenth century. The great warehouse complex of Albert Dock, Liverpool, built in the 1840s, has essentially the same structural characteristics. In the 1880s the Ditherington flax mill was converted into a maltings, for which it was successful until the 1970s when it fell into disuse. At this stage let me make three points. First, the existence of the building had been forgotten until 'rediscovered' in the 1950s; second, although we know who financed and built it, little is yet understood of the detailed circumstances that lay behind its innovative construction. That is the subject of a current research project. Third, the survival of this building has already been the result of one change of use, in the 1880s, driven by economic opportunity rather than conservation imperative.

Today, the building, which is Listed Grade I – thus affording the highest level of protection - is in the ownership of English Heritage who stepped in when the previous owner could not put together a workable package to renovate and re-use the mill. The objective is to put the building into sound structural condition, based on detailed research into its engineering design and current state, and then find a new user. Public access will be provided to part of the mill but its future will be dependent on a viable, non-heritage, economic model. Despite the exalted historical, engineering and architectural importance of the Ditherington flax mill, this approach to its future represents a departure from what one might call traditional heritage conservation approaches, in which structures – often ruins of castles or abbeys, but also great houses with their furnishings and pictures - were preserved for their heritage value, the public benefit lying in understanding, inspiration and education. In the case of Liverpool's Albert Dock too, a Grade I Listed structure that had stood empty for years, its future has been secured using a wide range of new uses including maritime museum, art gallery, apartments, shops and restaurants.

None of these new uses bear any relationship to the original purpose of these buildings. Two issues arise. First, we need to recognise that change of use has been part of the normal rhythm of buildings and their life cycles. Second, that once we recognise their heritage value, as opposed to their simple economic opportunity value, we need to develop sensitive mechanisms – in terms of design and engineering - that enable reconciliation of the historical significance with some form of new use, often involving safety, access and egress considerations unknown at the time of construction. This imperative has resulted in new forms of engineering and architectural process, indeed a wholly new profession.

The second example also involves the recycling of an important engineering structure, St Pancras Station, London, now the terminus for the Eurostar high-speed trains to and from Paris and Brussels. At the time of its opening in 1868 the iron trainshed, designed by William Barlow (1812-1902), had the widest span in the world – 74 metres (243 feet) - and the hotel fronting on to Euston Road was London's most luxurious. But, by the 1960s the hotel had been long closed and the station had fallen on hard times. Forty years ago the future of this great iron-arched trainshed and the hotel was in jeopardy and continued use as a railway terminus in doubt. Here, at the trough in the station's fortunes, Listing – again Grade I – meant that the threat of destruction could be mediated. Listing does not of itself protect, but it does demand a pause for thought and a formal appraisal and process before demolition or alteration can take place. In the case of St Pancras, Listing held the station in a limbo until the rest of the world caught up. Paradoxically, the inspired and hugely successful new use has been as a reprise of its former self, as an outstanding railway terminus rather than, for example, museum or exhibition hall. It opened in 2007 and the hotel reopens in 2010.

At St Pancras, detailed criteria were applied in the partnership between the owner, English Heritage, and the conservation architects and engineers. William Barlow's original drawings formed the starting point and in the replacement of missing elements his designs were meticulously adhered to wherever possible. Similarly, with the introduction of new ticket and check-in facilities, retail and eating, strict protocols were applied so that the new paid proper respect to the old. This ranged from maintaining the new glazed retail facades within the line and rhythm of the columned structure of the undercroft to careful control over signing and the use of company logos. The result is a triumphant exemplar of engineering conservation.

St Pancras has re-calibrated our view of great engineering structures; from liability to asset in one hit. It also affords us important lessons, not only for conservation but for contemporary architecture. Had the rigour of the St Pancras protocols been applied at, for example, Stansted Airport, Norman Foster's elegant pavilion might have survived the illiterate pandemonium of chaos that desecrates this and so many buildings – old and new - whose owners have little understanding of the quality of what they have nor sufficient understanding of how to manage them. And, of course, here in Dunedin we see New Zealand's finest railway station – and perhaps Dunedin's finest building – recognised and revered as part of the city's heritage, a clear example of public appreciation of a great and once unloved building.

The work of the civil and structural engineer, often of course working in association with architects, is both readily appreciated by the public and accords with our wider assumptions about what is and is not heritage, what is and is not significant. Normal heritage protection is also often both appropriate and effective. The mechanical engineering heritage is more complex and multi-facetted. Few rules apply when considering steam pumping stations, spinning or weaving mills and their machinery, collieries, metal mines or power stations. To a degree the same applies to railways and ships, both complex and often expensive prospects when it comes to preservation. Here engineer and conservator still need to find some common ground, in terms of philosophy, an understanding that these machines often hold prime evidence that can be easily destroyed, and that there needs to be a formal and clearly worked through reconciliation of whether operation is feasible, desirable or destructive.

Conservation plans, in which significance is defined and written down, principles established and a management regime determined, are absolutely crucial. All too often the 'it seemed a good idea at the time' approach to preservation causes real problems; that and the inability to say no when something turns up – however irrelevant to the current enterprise. Once an industrial site is preserved by volunteer enthusiasts, without proper strategic clarity on what the project is all about, it can become a magnet for everyone with a spare steam excavator, a heap of surplus firebars, or some odd lengths of railway line and nowhere to put them. The result is that the site starts to become a scrap yard, the public become confused and the nature and meaning of the engineering heritage retreats further into the marginal wastelands of mildly abnormal behaviour.

But it of course is in these fields too that the 'old men in boiler suits' are at their most effective. Their achievements are prodigious. These are the people beyond all others on which railway preservation depends - throughout the world. The same can be said for maritime engineering, almost anything powered by steam, or indeed, prime movers generally. They are both the mainspring of preserving the engineering heritage and their own worst enemies. Theirs is a focussed interest, executed on their terms, to their standards, as and how they want to do it. It has great strengths but fatal weaknesses.

Last year I have visited more than fifty preserved industrial sites in England, as part of a commission from English Heritage, to take a health check on the preserved industrial heritage and recommend some way forward. Most of the places I visited were in the hands of groups of enthusiasts. The universal strength was that these voluntary bodies had done what no official conservation agency had thought of doing. More than that, they had tackled pieces of equipment beyond the technical capacity, financial possibility or political reality of anything that official museums or conservation agencies could ever contemplate. In this sense they were truly pioneering.

They tend to be highly selective in their interests. Steam water pumping stations, those ultimate expressions of nineteenth century engineering virtuosity, have particular attraction. They were well built, beautifully maintained until they fell out of use and have proved to be within the capacity of volunteers with engineering skills, to preserve and – crucially important – to operate. As visitor attractions they are often less well run with, quite frequently, poor housekeeping, low standards of interpretation and few visitor facilities. As a result they attract many less visitors than they should. In short, it is the skills and knowledge on the one hand – engineering skills – that have achieved preservation and the paucity or often absence of all the other necessary skills, of making them really worthwhile for the public at large, which is their failing and represents the greatest threat to their continued existence. Here the points about exclusion that I made earlier come in. Time and again I came across groups who couldn't understand why a younger generation wasn't joining them, why they couldn't get financial support when they needed it, and were not accepted by the community at large.

(This section of the lecture will be illustrated by a number of examples – good and bad – of preservation practice.)

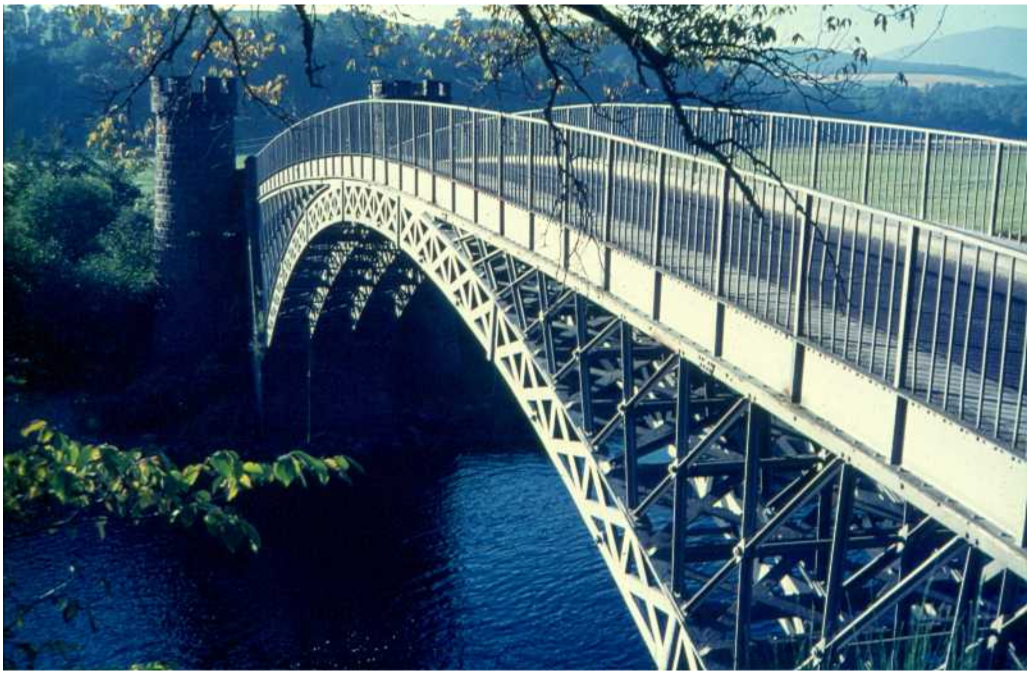
And yet, talking to visitors I would hear the lament that as an outsider there was nothing in the narrative that offered any understanding or way into the essentially impenetrable world of machines set out before them. A Lancashire mill engine, working in steam, might offer a tangible expression of pride in engineering workmanship, reflect the care and affection of its engineman, its central role at the heart of the mill and convey something of the capital investment necessary to keep an enterprise thriving and competitive. But, more often, information will be provided on its bore and stroke, the nature of its valve gear, its principles of compound operation, rpm and horsepower. Little will be offered about coal consumption, advantages over rival types, or relative cost of installation and operation; still less is anything likely to be said about those who operated it, their pay and conditions or their relative status within the complex hierarchy of a large industrial enterprise. When it comes to the wider world of community, locality or region, the message may well be lost altogether. All this reflects sectional internal interests that bear little or no relationship to historical or social circumstance or the intended audience - a form of institutionalised myopia.

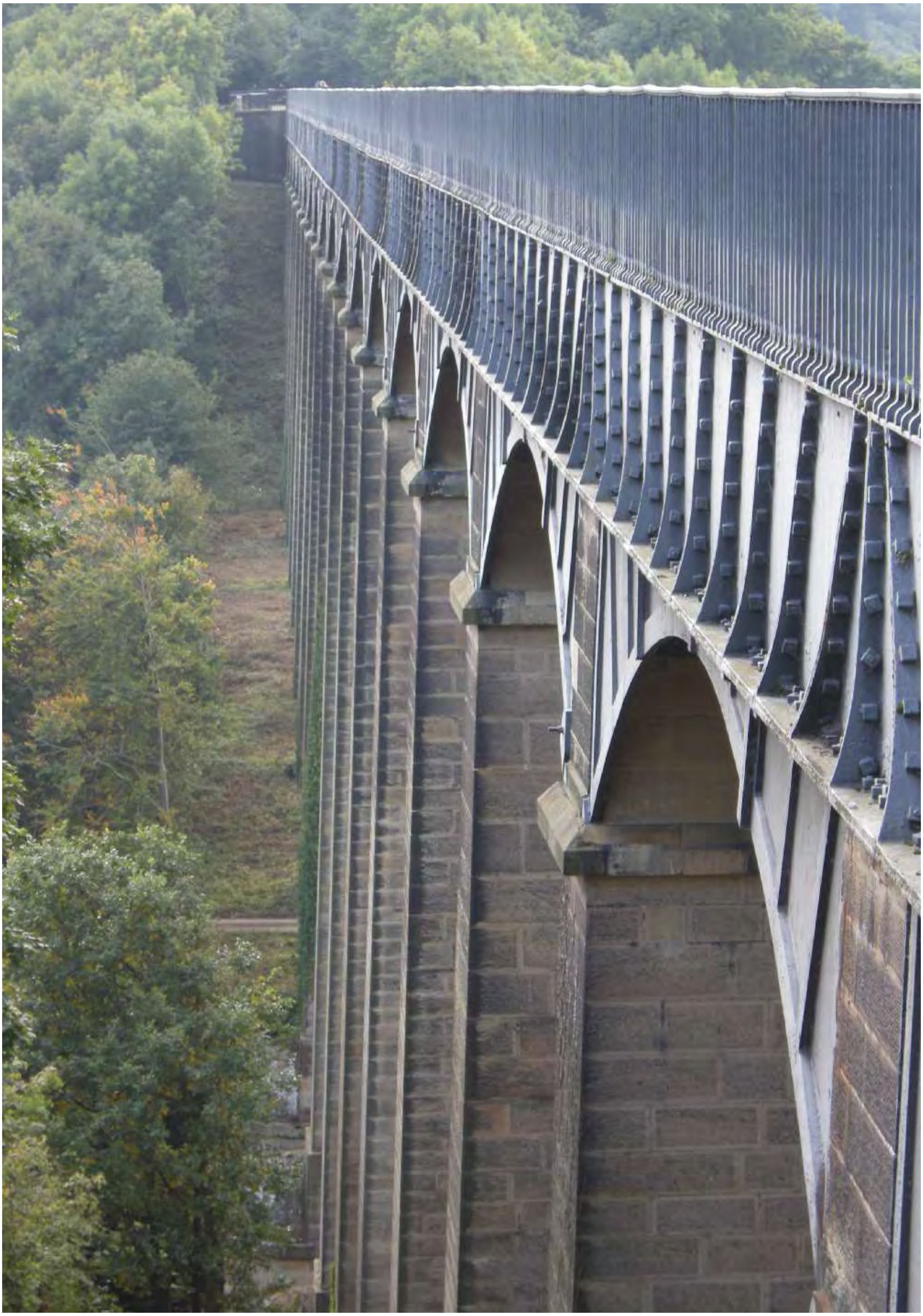
Let me draw together some of the threads. The engineering heritage matters. It should be important to engineers, as an expression of what they are and do, a part of their pedigree, and an inspiration for the future. It is important to the wider public - for the very same reasons. It needs to be seen by engineers and the wider public as an integral part of the wider heritage, indivisible from everything else that we wish to take forward with us into the future. It requires special skills and those in shortest supply are often the non-engineering skills to do with narratives and context, good visitor management and interpretation. To engineers my message is, spread the word to the rest of the world, get out of your professional bunkers and meet the people, ignite in them some of the magic of what it is that you do. And, join the heritage world. To the heritage sector my message is, marvel at the achievement of expert and enthusiastic engineers, recognise their qualities, help bring their preservation principles and interpretive skills up to date, and offer them a place at the table.

[1] Smiles, Samuel 1862. *Lives of the Engineers.*
[2] Hartley, L P 1953. The opening line in *The Go Between.*
[3] Southey Robert 1819, (*Journal of a Tour in Scotland in 1819* [with an Introduction by C H Herford, 1929]) p204.

Thomas Telford's suspension bridge across the Menai Straits, North Wales, one of the greatest works of art and engineering in the world.

Telford's Craigellachie Bridge across the River Spey, an iron arch of 1814 preserved as a monument in the landscape.





Thomas Telford's and William Jessop's cast-iron aqueduct at Pontcysyllte across the River Dee in North Wales, inscribed in 2009 by UNESCO as a World Heritage Site.

Pontcysyllte is the centrepiece of an eleven mile length of the Llangollen Canal designated as a World Heritage Site, which also includes Chirk Aqueduct.

Ditherington Flax Mill, Shrewsbury, the world's first iron-framed building (1796/7). Out of use for nearly thirty years the mill is undergoing structural repairs by English Heritage prior to a new use being found.

St Pancras station, London, reopened in 2007 as a reprise of its former function, as the terminus of Eurostar trains from Paris and Brussels.

Replacement doors and other detailing at St Pancras follows faithfully William Barlow's original designs and materials.

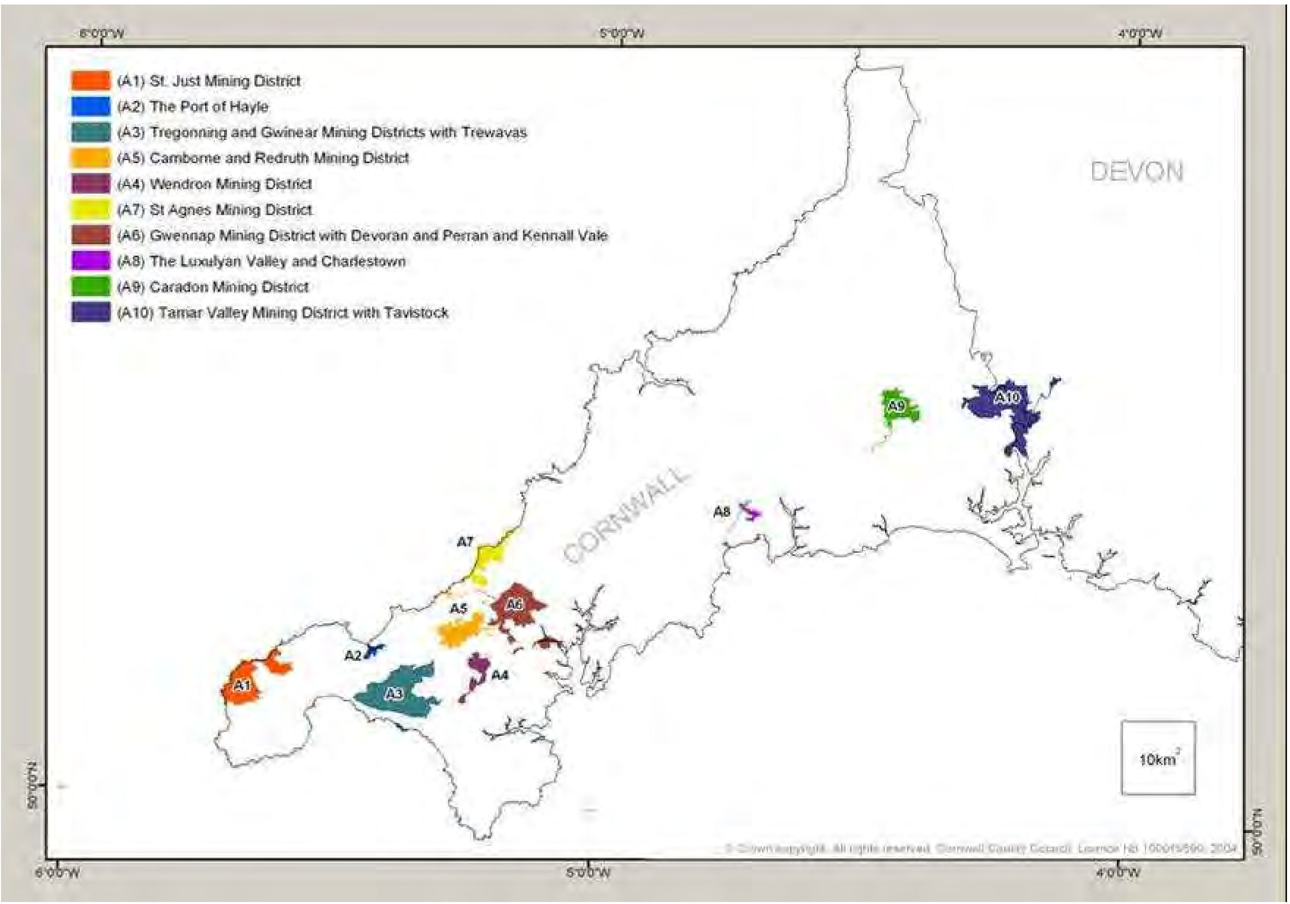
At Leipzig renovation of the historic station has created a retail destination and railway terminus.

The international dimension. The best preserved British-built gasworks in the world is in Dunedin; it may be the best preserved of any type anywhere.

The international dimension. Sugar cane crushing mill in Haiti, made in Liverpool in 1818.

The international dimension. Cylinder of the beam engine of the Haiti sugar cane crushing mill, built by Lindsay & Co near Liverpool, 1818.

Cornish engine houses associated with tin and copper mining are a prominent feature of the Cornwall Mining World Heritage Site. Similar evidence of Cornish mining technology can be found in Spain, Mexico, South Africa, South Australia and New Zealand. There are moves to nominate the first trans-continental World Heritage Site based on these remains of the Cornish engineering diaspora.



Map of the ten sites that comprise the Cornish mining World Heritage Site.

Cornish engine house converted to a dwelling.

Temple Meads Station, Bristol. Brunel's original terminus for the Great Western Railway is now an exhibition hall.

The ss *Great Britain*, the first large iron, screw-propelled ship, was launched in Bristol in 1843.

The *Great Britain* shortly after her return to Bristol from the Falkland Islands.

The *Great Britain* is preserved in the original Great Western Dry Dock in which she was built in the 1840s. The lower hull is protected from corrosion by enclosure in an air conditioned environment; the glass ceiling at waterline height supports a few inches of water.

Large scale preservation - in this case the iron and steel works at Voklingen in Germany - is rare. Volklingen, which closed in 1986, was declared a World Heritage Site in 1994.

Chatterley Whitfield Colliery, Staffordshire, is the subject of a major preservation project to secure the future of its extensive above ground remains. The rapid decline in deep pit coal mining throughout Europe has resulted in the almost complete disappearance of much of the evidence.

In Britain preservation of much of the engineering heritage is in the hands of voluntary groups. Here Papplewick water pumping station in Nottinghamshire is regularly run on steam by volunteers.

The oldest steam engine in-situ in the world, a Newcomen-type engine of 1795 at Elsecar in Yorkshire is not in operation. Debate centres around whether it is too important archaeologically to be brought back into steam.

The aviation heritage exemplifies as no other the growing capacity - especially of voluntary groups - to preserve aircraft both as static exhibits and in flying condition. Almost all the Concorde airliners built are preserved or the subject of preservation proposals.

Timber viaducts, once common as first generation railway bridges in North America and Australasia, are now extremely rare. This example, Percy Burn Viaduct, behind Port Craig, New Zealand is recognised by IPENZ for its heritage value.

Percy Burn Viaduct IPENZ plaque, 1990.
Note incorrect date, the viaduct was completed in 1925

Queen Street Mill, Burnley, is the last steam powered cotton mill in England, sole survivor of the many hundreds that defined Lancashire as the world's greatest cotton spinning and weaving centre. It is preserved and run regularly.

Invercargill Water Tower, a prominent engineering feature marked with a heritage plaque by IPENZ.

Invercargill Water Tower IPENZ plaque, 1990.

New Zealand's capacity to pioneer innovative engineering in the most obscure and isolated of environments receive worldwide fame in *The Last Indian*. It would surprise many to learn that the actual bikes still existed.

Managing Active and Redundant Industrial and Engineering Heritage Sites

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SUMMARY: *Management of active and redundant industrial heritage sites, including buildings, structures, infrastructure, landscapes, settings and equipment has been and will continue to be a challenging area of heritage conservation. Most heritage sites of an industrial nature are either under threat or will be under threat in the future as they become redundant and obsolete. Collectively these sites form a large part of the heritage of the areas in which they are found and they are the most difficult of all heritage sites to protect, retain, conserve, fund and find appropriate uses for. Most successful retention and conservation programs for industrial heritage places arise from large-scale redevelopment works where retention of some part of a place is required through a consent process or as one-off actions of committed individuals or groups to save a particular site or feature.*

Industrial and engineering built heritage and infrastructure has not received the same focus as private or government non-industrial buildings, landscapes or precincts. Consequently much of our engineering heritage will disappear and making decisions on what to try and retain and how to manage it is important if this aspect of our heritage is to survive.

1. INTRODUCTION

Most of our industrial or engineering heritage will disappear, in fact, very little will survive and what does survive is unlikely to be the most interesting, important or significant.

This may seem a depressing way to commence a paper on how to manage and conserve these places but engineering and industrial heritage have been well behind in terms of recognition and planning to protect their particular heritage values. A relatively small interest group fights for engineering heritage in contrast to other more generally accepted ideas of what heritage is. It is hard to move beyond the aesthetic and picturesque to engage the public in heritage understanding although the dramatic and the breath taking (as seen in activities such as the Sydney Harbour Bridge bridge climb) have placed some engineering heritage at the centre of public experience.

It is an interesting but probably sad reflection that engineering and industrial sites have more heritage ‘appeal’ once they are closed, interpreted, provided with a cafe and where they are integrated into a picturesque setting. Even innovative heritage places such as the blacksmiths workshop at Launceston Museum where almost nothing has changed or been removed since the last fire was put out lack that vital element of ongoing use that makes engineering/industrial sites most significant.

However, being realistic, industrial sites with high heritage value are unlikely to remain in use and retention, conservation, preservation, adaptation and interpretation can all assist in conveying their value to visitors and for research.

By its very nature industrial heritage is designed not to survive as unlike many other built features it does not often lend itself to adaptation or re-use and the cost of maintaining redundant industrial infrastructure is of such magnitude that without some form of economic return, which usually arises from use, the majority of industrial or engineering sites do not have a future.

This leads to several quite obvious conclusions:

1. Maintaining places in use is the best way for most sites to have a future
2. Managing sites prior to redundancy is the best way to retain and preserve significant sites
3. Understanding what is most significant and why is the best way to target places that should be retained
4. Focussing on a relatively small range of places better uses available resources to achieve hopefully better heritage outcomes.

This paper explores these concepts as well as successes, failures, funding, balancing often competing cultural values that do not consider engineering value as highly as other heritage values, the value of recording sites, interpretation, when to let sites and features go and when to fight for retention of engineering heritage. The issue of adaptive re-use and how that often removes core heritage values from engineering and industrial sites will be discussed along with the importance of strategic planning to enable heritage retention of vulnerable places.

1.1 Explanations

To avoid confusion, as this paper considers a very wide range of issues and places, I set out some guiding parameters:

1 By necessity the paper is general and there will be exceptions, I have not doubt, to many of the matters that are raised. This does not change the overall points being made about the difficulty of managing industrial heritage sites.

2 Movable engineering heritage is not specifically addressed. It is noted that there are substantial collections of movable heritage that vary greatly in quality and value, many are in museums, often locally based and some are held by organisations.

3 It is assumed that most industrial sites that become redundant cease their planned use and consequently an aspect of their significance is lost. The exception to this is the relatively large number of active railway museums where use continues.

4 OH+S issues often mean that industrial sites cannot be retained. This particularly relates to contamination but also general safety issues related to future uses.

5 There are many very active and often successful volunteer groups who operate former industrial sites such as railways. This paper, while making general comments about these types of sites, does not underestimate the value of this activity.

2. ASSESSING HERITAGE VALUE

No decision about a heritage site should ever be made without understanding the heritage value of the place and its component parts.

The heritage value may seem obvious for some places, but generally it requires considerable research and understanding to come to an informed and balanced position on what that value is and how it compares and relates to its locality, to other similar places, etc.

If a place is to be retained as a museum site without change then most values are likely to be retained, perhaps except ongoing active use. However most industrial sites that are approaching or become redundant do not become museums and will at best survive in small part. Understanding what is most significant about each place is essential to achieving good outcomes.

Major sites require a conservation management plan to guide decisions. The preparation of these documents requires its own paper as if these documents are to be useful they must achieve the following:

1 A good historical understanding of the place, processes and innovations

2 A clear statement of significance

3 A very clear analysis of the relative significance of the component elements of the place

4 A good comparative analysis of where the place fits into the broader range of similar places:

and when all of this has been understood;

5 Policy (rather than recommendations) on viable ways to retain and manage what is important.

As a general rule motherhood or generic policy statements in such documents achieve little. There are often complex and conflicting issues to be resolved in setting out policies for industrial sites that require careful preparation of policies.

A good example of a complex site is Goat Island in Sydney Harbour. It is partially used for shipbuilding and repair but also contains a collection of early colonial buildings. The island, once the base of the Maritime Services Board in Sydney, is now part of Sydney Harbour National Park and is in the process of planning for the future.

The island has an overlay of exceptional colonial powder magazines, wharves, barracks and quarrying with one of the last active shipyards in the harbour. The shipyard use has an adverse and major impact on the earlier structures and features, but clearly both are significant.

The CMP involved extensive analysis and comparative study (around the world for some aspects of the site) to determine the relative values of the components parts so that any policy that provided for the removal of parts of the infrastructure could be supported on the grounds of significance as a primary reason.

Figure 1. *Goat Island, view of shipyard.*

Figure 2. *Goat Island, Colonial Powder Magazine*

This raises the issue of why would removal of parts of a place be considered if they are significant? In the case of Goat Island, which exemplifies many of the issues that are found on most industrial heritage sites, some of the reasons for developing policy that considered quite radical options for the future were:

1 Much of the infrastructure is in poor condition, some collapsing requiring complete replacement, e.g. wharves, and some no longer capable of operation.
2 The cost of repair to features such as wharves alone exceeds the whole operational budget of the place.
3 Rising sea levels, that are already evident on the reclaimed areas of the island, will see a number of structures and features underwater in the future.
4 The operational standards of the shipyard require extensive upgrade that will adversely impact on heritage values.
5 The costs of upgrading the shipyard to commercial level will not provide for any financial return.
6 The costs of conservation, restoration and adaptation of the colonial and most significant aspects of the place are very high and alone require substantial funding, further funding is unlikely for other aspects of the place even though also significant.

While this is a simple analysis, it highlights the difficulties of maintaining even high profile sites in the centre of a large city where there is a high level of visitation possible.

3. MANAGING ACTIVE SITES

There are no operating engineering or industrial heritage sites that are easy to manage for their heritage values.

Fortunately there remains in some government and private organisations a pride in what has been achieved in the past that reflects in the way elements from the past are retained. More often, however, economic considerations dictate that replacement is a better option than repair and that new technology must replace older technology.

A model study is the Hydro Tasmania approach which I delivered a paper on at the last conference. It was model as they committed to understanding their history and what was significant before determining changes and then they assess the impact of change against heritage values and, where possible, and it is not always possible, make decisions taking into account heritage values.

A small but good example of this is a small and remote Tasmanian Dam where a safety assessment determined that the dam wall was at risk of collapse due to its construction. While in my non-engineering view this was a poor recommendation based on only empirical analysis and current design standards and without the benefit of understanding how the dam wall was built, the decision had been made to rectify the problem. Through review of the decision it was possible to retain a large part of the original construction without alteration and to solve the non-compliance. This only happened because the dam had been identified as having high significance in a heritage study and a review process was triggered by proposed works to places of that level of significance. Alternative design solutions could then by explored to try and resolve the issues of heritage value and ongoing use.

Often the solution is to reduce the amount of work or change taking place and to only do what is needed to address the specific problem. What tends to take place is that a much broader scope of works develops around a problem that has consequential impacts on heritage value. With this dam the solution was to only concrete line the spillway, which was the high risk area and to retain the flanking dam walls with their finely crafted stone facing.

Figure 3. Hydro Tasmania *Dam with stone walling of heritage value.*

This also raises the complex question of the heritage value of old technology when that technology is no longer appropriate in a working complex. It is far easier, for example again looking at a hydro site, to retain heritage values in inert features such as buildings, pipelines, dam walls, etc., rather than in the power generation units and the electrical or control systems. Solutions that retain the appearance of a place but provide for replacing the operating systems are not that hard to develop but I would suggest that much of the real significance is then actually removed.

A common suggestion, in attempts to retain heritage value at active sites, is to remove a piece of equipment or infrastructure that is redundant and relocate it to a museum or repository to provide an example of the design, technology etc.

Figure 4. *Tungatinah Power Station, the turbine has been rebuilt within the existing chamber and casing, retaining the appearance but not the fabric.*

It is in situations such as the one outlined above that retaining elements as museum exhibits can have a value, preferably they are retained on site near their original location but this is not always possible. It is also important to establish if items are being keep purely to retain material evidence of past equipment or features or if it is to have a display and interpretation use.

Some organisations maintain their own museums or collections and manage them well providing for interpretation and public access. If items are simply left near their original locations there is a high risk of long-term damage and accidental loss.

Clear planning and policies are important to manage removed or relocated heritage items.

A less successful, in my view, integration of heritage elements into a working system is found in much of the recent upgrade work undertaken by State Rail in NSW. This probably occurs on other rail systems as well.

State Rail has undertaken many heritage studies and have very good records and understanding of their heritage, built, technical and operational. Putting aside steam operation which survives in museum form due to the high level of interest and commitment of enthusiasts, the general operating system has struggled to conserve its heritage with upgrade requirements and a failing level of service and operation.

Figure 5. *Bomaderry Railway Bridge, built but never used and now collapsing.*

Even sites and infrastructure considered to have rarity and high significance continue to be lost or compromised by upgrades. Perhaps this is inevitable and we should only expect a small remnant of the heritage of an old operating system to survive.

One of the greatest enemies of heritage conservation in operating systems such as rail networks is the corporate zeal of management to unify and re-badge. This is seen in regular upgrades of signs, fences, pavements, paint schemes, use of standard and usually inappropriate (for heritage sites) materials and an often unbalanced focus on removing liability from the organisation for what may happen on its property.

While there is no real argument with making places safe and easy to use for the public, using unsympathetic standard elements on important heritage sites is both poorly informed and denigrates the heritage values that our being espoused in the studies that are undertaken before upgrades occur.

A simple solution is to develop a secondary set of materials and finishes that are appropriate and complying for use on particular heritage sites. This need not be expensive or onerous and can achieve very good heritage outcomes. It requires a major change in corporate thinking however to achieve.

A difficulty in arguing for retention of heritage values at many engineering sites is the inability to provide access or interpretation as the sites are not accessible. An element of a place's significance is always tied up with the ability of the place to demonstrate its value and while the item or technology itself can be of great significance, when it cannot be publicly appreciated it can be harder to justify retention. Some elements are of such significance that being accessible doesn't matter, others rely on being able to be seen or accessed.

An example of the difficulties of public access can be seen at a number of Hydro Tasmania sites where public access has in the past been encouraged with picnic grounds, small visitor centres and museums and guided tours of major sites and features including operating power stations. This provided a high level of public interaction and appreciation of the technology and allowed for extensive interpretation. Difficulties with OH+S and liability, the cost of staffing and maintaining such activities as well as a decline in visitation has seen them all close. Interestingly those features themselves, designed to appreciate the heritage of the operation, are now part of that heritage and at risk of being removed and lost.

A key factor in achieving success in terms of heritage management of operating sites is the attitude of the senior management of the organisation to heritage. Without appropriate funding, programs of works, commitment to achieving good standards of work and a level of flexibility in approach to important heritage sites, little will take place to achieve heritage outcomes.

The corollary of this is having realistic expectations of what can be achieved to conserve heritage and maintain an operating system. Not everything will remain and compromises will be required, a level of pragmatism is essential to achieve even modest outcomes.

Understanding what is significant and why it is significant will underpin arguments for retention of heritage values.

4. MANAGING SITES ABOUT TO BECOME REDUNDANT

Often there is little warning about the closure of industrial or engineering sites that have heritage value, which gives little time for planning or negotiating about their future. Often the land on which these structures and elements are located is valuable and there is no intention to retain even parts of the place for their heritage value. Heritage is seen as an impediment to future development.

Recent examples, such as the CUB site in Sydney, illustrate the intensity of development pressure in cities and the limitations on retaining heritage elements. Generally features that are retained are the architectural elements of an industrial site that are more capable of productive adaptation. Very little infrastructure, machinery or equipment is retained on these sites.

The ideal situation is where an organisation prepares for redundancy by undertaking a heritage assessment, determining how to deal with important heritage features and elements and incorporates heritage in the future use, sale or development of the place. Some local councils or authorities will insist on this taking place and where development pressure is high can have considerable success in retaining heritage features. However this is not always the situation and inaction on more peripheral sites will see the place deteriorate to the point where usually it cannot be realistically saved.

An interesting example that illustrates a number of difficulties in planning, approvals and retention is Wangi Wangi Power Station near Newcastle in New South Wales.

Prior to closure of the station a detailed study was undertaken by the power agency of its equipment and infrastructure. Each element was graded for significance with recommendations of what was essential to retain for heritage reasons. The building itself is significant but probably not as important as what it contained. Having undertaken the study the power generation authority planned for disposal of the site and remediated the place by removing all equipment and in the process doing considerable damage to the building. The place has remained in this deteriorated state since. The site was acquired privately and plans prepared to re-use the building effectively to build a small town within the shell of the vast structure. Part of the proposal was to add several residential levels to the top of the building to take advantage of the superb views. This was initially refused on heritage grounds as it affected the form and appearance of the former power station building. This was appealed and on review the work was approved, but not without much argument and persuasion based on the alternative being the loss of the building.

Figure 6. *Wangi Wangi Power Station*

This highlights several fundamental issues for engineering heritage.

1 Despite a very fine study, recording and analysis, nothing was retained of the operational part of the place apart from the building and chimneys and these were allowed to fall into very serious disrepair.
2 When a change was proposed that gave some chance for the place to have a future it was resisted because of purported heritage values, even though the major heritage values had already been lost and finding a new use was the only way to save any part of the place.
3 Comparative research of disused power stations around the world (in this example) revealed that apart from sites such as the Tate Modern Gallery in London - an adapted power station - that almost none of these sites survive as they are too hard and too expensive. When this is understood considering change, even considerable change to a place, becomes more reasonable and is usually the only way of maintaining anything for the future.

Wangi Wangi is unlikely to have a viable future apart from a development site with perhaps a few remnants of the station retained. Large redundant engineering sites generally have very little prospect of being retained.

What then should happen to these sites in terms of planning for redundancy?

The usual answer is archivally recording the place. This is valuable but limited as it usually takes place after closure when much of the fitout has been removed.

A better option is recording while in operation which gives some understanding of how the place functioned. Ideally recording should include oral and written history, film and still photography and collecting records of the place.

I have over many years recorded a large range of sites including hospitals, power stations, hop kilns, cement works, prisons and railway sites but most had already ceased use. The resulting recording while evocative do not reflect the heritage value of what has taken place.

An often suggested use for parts of larger sites is as a museum displaying the history of the place. In very few situations is this viable or appropriate. Interpretation of the history of the place as part of new development is sound and widely undertaken and can be very creative in engaging public interest. Sadly, however, interpretation can often be token and not engage with the detail that is important on engineering heritage sites.

Working on many industrial heritage sites has revealed that there are no fixed ways of approaching their management - apart from understanding their heritage values first - and that opportunities need to be defined for each place.

The heritage outcomes for sites that are to become redundant will be determined by:

1 The heritage values of the place and its component parts,
2 The location and accessibility of the place for visitation and interpretation,
3 The potential to develop uses that are viable as well as compatible that allow some of the heritage fabric to remain,
4 The financial resources available,
5 The level of adaptation that is possible before its heritage values are unacceptably compromised,
6 The commitment of the owner/manager to heritage.

Balancing these factors can be difficult.

5. MANAGING REDUNDANT SITES

Redundant industrial sites are in some ways the easiest but in other ways the hardest to manage. The level of difficulty depends on a range of factors but principally where they are located and what potential they have for adaptive re-use. The more 'industrial' the site the harder it usually is to adapt or at least adapt and re-use successfully. Sites of just engineering value, that is without buildings or other usable or adaptable structures, such as bridges or industrial plant are very difficult generally to manage once they are redundant.

The following section looks at a number of case studies to illustrate some of the issues in planning to retain heritage values at redundant industrial/engineering sites.

5.1 Hop Kilns

One of the most evocative and interesting industrial site types I have worked on has been Tasmanian hop kilns and their related infrastructure. There are about 40 extant kilns in the Derwent Valley of varying designs and built mostly of brick or timber or a combination of the two. Many kilns retain their operational equipment, some movable heritage and a range of interesting technical features. Kilns comprise a drying floor or metal mesh on slats, heated from beneath with wood, coal, gas or oil furnaces and one or more levels of drying floors, often with low head heights, sometimes only 1.5 metres in height. The lower floor of many kilns retain hop presses, loading docks and bays, rakes, paddles, metal labels and other material.

The most significant and robust kilns are in a single group and ownership and there have been concerted attempts by the owners to develop uses including tourism, accommodation and commercial use. They are however located in relatively remote locations and are not in Hobart or a days travel from it making accommodation difficult.

The remaining kilns in the Derwent Valley have had relatively little other use apart from low-grade agricultural storage. Several have been adapted for residential use that has involved extensive reconstruction so that only the outer form of the buildings remain. Compliance with building codes has not allowed original fabric to survive. One is used as a gallery and restaurant with reasonable success.

Many of the timber kilns, having been out of use for 40 years, are in very poor condition and will be lost along with their workings. Several have been demolished due to their poor condition.

These are iconic industrial structures that are not only significant for their engineering and industrial heritage but as visual landscape elements in a very significant modified landscape. This is a rare example of industrial heritage defining a picturesque landscape and the whole landscape deriving from the growing and processing of hops.

The sites are managed by individual owners, some of whom take an interest and look after the buildings and equipment and most of whom do not maintain the structures.

This is a building type that does not easily convert to other uses, and only one or two can be adapted for public uses as they are relatively closely located and duplication of uses is not viable.

Despite considerable research and work there have been no long-term uses found for the majority of the buildings and infrastructure.

5.2 Railway Buildings on disused lines

While railways, at least in NSW, have been stripped over many years of their heritage attributes and as already noted in this paper have been dumbed down by the corporate branding of the system, some quite intact railway sites remain.

I first took an interest in railway structures and technology in the mid 1970s when I surveyed a large part of the NSW railway system (completed in the later 1980s) for a thesis on railway structures. This was followed by a second post-graduate thesis on how to establish the heritage of railway buildings and structures. During that period I recorded many of the railway sites in the state. This was at a point where line closures and major cutbacks were taking place and in conjunction with the National Trust I prepared a record of what remained.

Re-visiting some of these sites in recent years is depressing as highly significant sites with fine groups of buildings, technology and infrastructure have disappeared completely, often without trace.

Fortunately disused lines generally remain in government ownership and some are simply abandoned leaving a fascinating legacy.

One location by way of example, Dumaresq, outside Armidale retains almost all of its site features as last operated. Some of the rail sidings and points were removed earlier as use declined, but most elements remain.

Figure 7. *Dumaresq Railway Station*

The site was established in the 1880s with a station building of three attached pavilions, a brick platform, station signs, signal frame (now disconnected), station masters residence (now in private ownership and well maintained), point levers at each end of the yard, a home signal, road crossing with rails, remains of gates, culverts and a grain shed. The place has general grounds maintenance presumably provided by the owner of the residence but otherwise is unattended and unused. The station building is used for storage and is secured, because the residence is close and occupied the place has not suffered from vandalism.

Figure 8. *Dumaresq Railway Yard with abandoned infrastructure.*

As the place has not required upgrades to satisfy constantly changing OH+S requirements, has not been subjected to standardisation and new low grade materials, signs and fitout and has not been upgraded it retains an amazing connection with its past and encapsulates traditional railway operation and practice in country NSW.

But does it have a future? And what of all the other similar infrastructure that is abandoned?

As the line and trackwork exist, even though not operational, it remains a railway and cannot be disposed of in the event that the line could be re-activated. Based on the practice of removal of most redundant railway buildings on active lines it could be assumed that as the site features deteriorate they will eventually be removed unless there is a specific plan to retain the place for its heritage values.

What makes it unusual now is it intactness and its mid Victorian date which exemplifies railway development in Australia. What makes it difficult is that even though close to a significant country centre, it is out of the way and unlikely to attract visitation or uses that would provide for public access. Even if the place could be sold, as some disused railway sites have been, its most likely use is residential or as an adjunct to a residence. Small railway buildings do not lend themselves to contemporary living without considerable change.

Whatever the outcome for sites such as this, it is unlikely that they will retain the quality of intactness that presently exists.

5.3 Bridges

Bridges represent engineering achievement at its peak from our earliest structures to contemporary bridges.

Bridges fall into several categories:

1 Major bridges, usually but not always remaining in use, that are generally not under threat and which are well maintained. These range from colonial stone bridges, through various types of steel bridges to concrete in the twentieth century.

2 Minor bridges often of timber or steel or a combination of both and more recently of concrete. These bridges are more often found in the country outside towns, are often modest, narrow and require considerable maintenance. They were built in the case of rail and road as part of low cost railway construction to open up the country or where materials were difficult to access or across minor waterways on minor country roads.

Over time as roads and conditions are upgraded all of these bridges will be scheduled for replacement with new wider, better graded, better aligned bridges. Rarely does a replaced bridge survive, even if located adjacent to the new bridge, as they quickly fall into disrepair and become dangerous. Most replaced bridges are not of high individual significance but their representative value as a feature of the landscape is disappearing quickly. There are some notable exceptions where early bridges are retained adjacent to their replacement structure.

In attempts to preserve some of the engineering heritage of bridges, even relatively common bridges on operating roads and railway routes, studies and reports have been prepared by various authorities to identify structures that could be retained as examples of what once proliferated. Suggestions have been made to retain good examples in varying locations or to retain a group of similar structures on a single road or railway line where they can be maintained with greater ease.

A rare example of redundant bridge that has not been removed is outside Armidale in NSW where a small over-rail bridge remains adjacent to a new concrete bridge.

It only survives as the railway line is abandoned and the bridge presents very little risk to anyone. As the structure slowly deteriorates and fails it will inevitably be removed.

An example of very significant bridges that are redundant are the small stone bridges along the alignment of the old Midland Highway in Tasmania that are now abandoned with adjacent new road construction. Some remain in use on back roads but many are now on private property and no longer maintained. These are convict built engineering works of fine quality that require maintenance. They are gradually being recognised for their heritage value by heritage listing.

Another example of a major timber bridge, abandoned but retained for its heritage value is the timber trestle bridge near Gundagai in NSW. It is a spectacular structure that is increasingly in poor condition and which will require major conservation work if it is to survive.

Figure 9. *Dumaresq road bridges, old and abandoned and new beyond.*

5.4 Fortifications

Australia has an extensive collection of fortifications dating from first settlement of Sydney through the Crimean, the American War of Independence, the First and the Second World Wars. Often forts are overlaid on earlier structures because of the commanding positions they occupy.

Collectively they represent a major engineering achievement as well as a fascinating historical statement about our development as a country. Like many major public works most fortifications were redundant before they were even complete and their designs suffered from poor decisions about how to protect Australian ports and harbours. Nearly all of the fortifications around Sydney Harbour, which I have studied are long redundant and most have been abandoned, often stripped of fittings, sometimes infilled and mostly dangerous. They are however an extraordinary collection of structures with an amazing engineering and technical history.

Most of the Sydney forts are owned and managed by DECC National Parks and Wildlife Service or the Sydney Harbour Trust. Some sites are under separated ownership and management.

Figure 10. *Middle Head Sydney Accessible Fortification*

Figure 11. *Middle Head Sydney Non-Accessible Fortification*

Basic maintenance and security of the collective sites exceeds the operating budgets of the managing bodies. Conservation work, which does take place on selective sites, is expensive and by necessity very limited. Only the most interesting structures are maintained.

I was involved in preparing a strategic plan of management for the NPWS forts sites around Sydney and a number of policies developed that are of interest.

1 Firstly it became obvious that the cost of proper conservation and management of sites, many of which are underground, exceeded any potential budget that could ever be allocated, consequently most sites could not be maintained. This meant that those sites would have to have a management strategy that allowed continuing deterioration but provided basic safety to prevent collapse of structures etc.

2 Secondly it meant that high risk sites needed to be sealed off, if that was possible, or for some remote underground sites that were subject to regular break-in and vandalism, infilled with sand for safety. This was a dramatic policy that has not yet been acted upon but which will, once an accident occurs at a site, be adopted quickly.

3 An approach to site safety, given that many of the sites have high visitation and high risks under current OH+S regulations, was developed to address high risks but not all risks as the sites by their nature contain a high level of inherent risk. This has been adopted but caused considerable fear as risk is now one of the major forces that dictates heritage outcomes.

   The approach was simple and was based on identifying areas of public access that was planned or intended (such as paths or picnic areas), providing warnings were there were sudden level changes, known lookout locations or stairs that were heavily accessed by the public, providing safety fences to key areas such as lookouts and guide fences with a simple top-rail for other areas to indicate that there was a changed condition. Dangerous routes were re-directed to prevent obvious hazards and short-cuts blocked. General signs warning that only specific areas were fenced were located at all entry and path commencement points. Undergrowth was used to deter access from dangerous areas around paths and the balance of the site was treated as a natural environment with standard NPWS approaches to bush areas.

   These works in themselves were costly but relatively modest when compared to other approaches.

4 A similar approach was taken with maintenance. A basic schedule of works was developed to prevent ongoing deterioration and to provide higher levels of security. High risk areas were identified for immediate remedial or stabilisation works. Schedules of work were then established for key sites.

5 Two sites were identified as having potential for significant future works, visitation, public access and interpretation. These were both of National significance.

6 A major funding proposal was recommended not only to conserve the engineering and military heritage but to enhance the visitation as a destination of National profile.

What is particularly important from this study was the acceptance that inevitably only a small amount of conservation could take place even though the place is of such high significance and then managing it within that framework.

5.5 *Overlooked heritage sites*

Australia has a vast collection of overlooked engineering or industrial heritage sites. It is an aspect of our heritage that although recognised in heritage studies and thematic studies does not fare well when no longer required. Often industrial sites are considered a blight to the locality and undesirable and as residential development constantly expands into former industrial areas there is increasing pressure for industry to cease and relocate, long standing sites often of considerable heritage value are more valuable for other development and disappear.

Many remote sites are also overlooked. I have visited closed and abandoned cement works, brick works, power stations, mines, quarries, railways and foundries across NSW often recording them (many without consent). Apart from photographs and sketches, for the sites that I have visited that I have taken and no doubt others have similar experiences there remains no formal recording of many of these places that were often important industries and employers for whole communities.

5.6 *Ruination*

A relatively new concept in heritage planning is retaining sites in a ruined form and allowing them to gradually deteriorate until they reach a point where they disappear. The concept is new only in the sense that the heritage movement seeks to identify, heritage list and then maintain places of heritage value. The idea of allowing significant places to continue to decay is hard to accept and plan for.

Figure 12. *Henry Head Sydney Abandoned and accessible fortification.*

It is particularly appropriate for engineering heritage where many significant features are robust and can stand with slow rates of decay. As an alternative to clearing sites when redundant, where there is no pressing use for the site as is the case with many country locations, simply making it safe and leaving it can provide a strong understanding and interpretation of the landscape and land uses.

Ruination can be seen in old mining sites that have not been remediated, routes of abandoned railways with cuttings, tunnels and embankments, early farm buildings remaining in the landscape used as hay stores and the like, the remnants of dry stone walls, remains of timber bridges, culverts, quarries, etc.

The policy of ruination dominates the strategy for managing the fortifications of Sydney Harbour - there is to be no attempt to recover the forts but to manage them as ruins with safe access and interpretation.

For ruination to be successful in allowing people to understand what has happened it needs to be planned. This appears to be a paradox, but if for example a section of railway is allowed to remain as a ruin without remediation and removal of the evidence, its form and detail in the landscape provides all of the clues necessary to understand what happened, where it operated and how it worked. The planning is to ensure that sufficient remains to tell the story of the place.

For many engineering sites ruination is probably the best chance of retaining features and aspects of their significance.

6. IS THERE HOPE FOR ENGINEERING HERITAGE?

There is sufficient interest and activism within the community and amongst engineering and heritage professionals to ensure that some engineering heritage survives. Given the vast amount of engineering heritage that has existed, what does survive will be a very small segment.

What then is most likely to survive?

Firstly heritage that involves passion on the part of those conserving it. This often focuses on working heritage such as steam museums where the operation of the heritage items within a context motivates both the conservator and the public. There will always be visitation of these sites by enthusiasts but more importantly by the broader public.

Secondly high profile sites where development deals are made that provide for retention of aspects of the history and heritage of the place. This may involve some museum display but is more likely to be interpretation within an adapted structure sometimes using interesting remnant equipment or machinery.

Key heritage sites identified by government agencies where there is a commitment to retain and maintain heritage features. These are often higher profile sites or sites with a range of heritage values that include engineering heritage.

A miscellaneous range of sites in private ownership or management where the heritage features or structures can co-exist with other adaptive re-uses and which may enhance the appeal of the place for commercial or tourist activity. Retaining working equipment in hotel rooms such as IXL Jones in Hobart or the Q Station in Sydney has an appeal to guests who are looking for a ‘unique’ experience.

A small number of museum sites such as Waddamana Power Station which also allows the display and interpretation of collected heritage from related sites.

Engineering or industrial landscapes where the engineering works have modified the site and setting to such a degree that it is not possible or desirable to return the site to an earlier form. Some of these sites are evocative - Mort’s Dock in Sydney - becoming landscape features apart from their engineering or industrial value, others cleverly manage the heritage elements in creative ways - Paddington underground reservoir park -to retain the heritage fabric.

Some abandoned industrial or engineering sites where there is little pressure for development and heritage features remain through their robustness. Mining sites or places like the early hydro site at Armidale where weirs and flumes now form part of walking tracks in the national park

7. CONCLUSIONS

High profile engineering sites will survive as a record of the major engineering achievements. Apart from the buildings related to engineering heritage sites light houses, power stations, some maritime sites, bridges, etc will be represented as both operational and redundant heritage sites.

Other engineering heritage will survive to a much lesser degree and mostly when there is a concerted local interest group who are prepared to be active in preserving the particular place. This restricts heritage conservation to areas that have an appeal and where there are sufficient people prepared to contribute.

Private engineering conservation is of very small scale and cannot be relied on as a strategy to retain important sites. A client showed me a superbly restored horse driven water pump from the 1820s that he had preserved and conserved when he accidentally discovered it on his property. Even though his property was of high significance and interest with many fine heritage features of great appeal, their location could not support any sort of public use or access that allowed him to undertake further works on other features of equal interest.

How do we manage and conserve engineering heritage? We keep maintaining pressure on the major owners and managers of this heritage to identify, manage and conserve their heritage responsibly and we keep the profile of this once neglected area of our heritage high.

THE ENGINEER AS LANDSCAPER AND CULTURAL WARRIOR

Illustrated lecture by Professor David Dolan

SUMMARY: *In 1910, American philosopher William James called on governments of all nations to eschew fighting each other, and instead jointly pursue "the moral equivalent of war"— a War Against Nature. Believing the world to be fundamentally hostile to the human struggle for survival, James was inspired by the projects of the great nineteenth-century engineers. He saw their work as a grand cultural endeavour, transcending merely building infrastructure to solve local practical problems.*

Pipelines, railways, roads, tunnels, bridges and canals tie formerly separate places and people together, creating new political, economic and population zones. The engineers of the Victorian and Edwardian era literally reshaped the landscape and redrew the maps, changing forever the ways we experience, conceptualise and understand the environment. In the context of the British Empire, impressive engineering works were articulated to enhance the credibility of the imperial enterprise.

The visual impact on the physical landscape was controversial, but the new spatial and cultural reality they created is reflected in landscape art and popular national imagery. The fame and drama that surrounded C. Y. O'Connor in Australia and New Zealand, and his international peers, made them significant cultural figures in their own right, as influential as literary or visual artists in creating cultural imagery and sense of place.

1. THE ENGINEER AS LANDSCAPER AND CULTURAL WARRIOR

When we mention engineering heritage, we most often think of structures such as power stations, dams, harbours, pumping stations and pipelines, and road and rail lines with their embankments and tunnels.

The shared engineering heritage of New Zealand and Australia includes the dispersed work of C Y O'Connor, who is particularly famous in my home state of Western Australia (WA) where his name is forever associated with the opening of Fremantle Harbour, the growth of the railway system, and the Goldfields Water Supply Scheme (hereafter referred to by its shorter and colloquial local name "the Pipeline").

Before coming to the Antipodes and changing some of their landscapes forever, O'Connor's prior learning experience was in railways in Ireland where he was born and educated. Ireland was then entirely if uneasily under English rule — colonial rule, really: at the time of his birth the Irish Free State was 80 years in the future. O'Connor is important here for what he represents: he was a product and representative of the European and British culture of heroic engineering, which includes such names as the Brunels (father and son), and Ferdinand de Lesseps of Suez fame. As a young professional engineer in Ireland, O'Connor did not have control of major projects: that was to come in Australia and New Zealand. As for so many others, engineers realised that the colonial empire provided challenges and opportunities for work on a larger scale than at "home", and potentially for fame and glory.

A couple of years ago I was interviewed on ABC radio as part of a discussion about how it was possible for such large-scale projects to be undertaken in the 19th and early 20th centuries. In the angling of the program, there seemed to be an implication that today's governments are reluctant to undertake comparable infrastructure projects. Whether that is really true as a generalisation, and if so why, is beyond my scope here, although at the end of my talk I will offer some suggestions about negative as well as positive aspects of the heritage of the era of heroic engineering.

My purpose is to discuss a number of cultural implications of these grand 19th century projects of which there are many examples such as O'Connor's Western Australian pipeline which is generally regarded as much more than a piece of infrastructure, having achieved recognition as a major component of the state's and indeed the nation's cultural heritage. For example, when the National Museum in Canberra opened in 2001, the "Golden" pipeline was — as far as I could see anyway — the only representation of WA in the permanent exhibitions.

Such recognition of industrial and engineering heritage is not unusual these days. All around the world, bridges and forts, reservoirs and power stations (the latter only when decommissioned, it seems) are entered on heritage registers and feature prominently in the imagery of tourism and political nationalism. This is of course a relatively recent development. In the early days of heritage listing, the emphasis was on colonial domestic architecture, churches, and public buildings rather than public works. And when we investigate the story of some great examples of engineering heritage, it becomes apparent that what we now greatly admire, and desire to protect, conserve and interpret, was often initially regarded as destructive of aesthetic and heritage values as then understood!

Everyone knows that large-scale engineering projects such as railways, highways, ports and water supply schemes changed the appearance of landscapes. The prime mover in all of this has been and is population growth and movement and specifically urbanisation. New and growing — and often sprawling — cities not only permanently change the landscape where they are built, by replacing open land and woodlands and wetlands with buildings and roads and infrastructure, but they also impact on the landscape far beyond their boundaries. As well as accommodation for residential and work purposes, the concentration and number of people demands infrastructure to provide water and sewerage, energy supplies of all sorts, and of course food production and raw materials.

In European countries, the industrial revolution of the 18th and 19th centuries and simultaneous population growth meant not only the steady expansion of existing older cities like London and Paris, but also the birth and sudden growth of vast new cities where there had previously been only small towns or villages: obvious examples are places like Glasgow and Birmingham. The pattern in Australia and some other colonial societies was comparable to the latter scenario. Small indigenous populations were rapidly outnumbered and rendered politically and geographically marginal (at the very least) by hordes of immigrants. The extreme case of this was of course a gold rush, which suddenly brought thousands of people to places like Dunedin or Bendigo or Kalgoorlie where there was no infrastructure and their physical needs could not possibly be met from existing local natural resources.

2. SCARS ON THE LANDSCAPE ?

Then as now, the hasty sprawling of cities old and new was applauded by those who profited from it, and detested by those who had to live with the results of it — and also by those who regretted the loss of rural landscape and habitats. Today, when we have planning commissions and planning laws and a planning profession, we still manage to produce some horribly ugly and environmentally unsustainable urban and suburban developments, when speculative greed and so-called "property rights" are given priority over the long-term public interest. But in England during the industrial revolution and the first part of the 19th century, there were no planning controls: "Go for it, build those tenements and future slums, and decamp with the profits! You'll be rich and won't have to live there."

The irresponsible and environmentally damaging urban and suburban development of the 19th century eventually led to calls for planning controls, and to schemes to do it better, such as the Garden City and City Beautiful movements, and of course the birth of the National Trust which was initially focussed on protecting rural landscapes and places for recreation: "vast outdoor sitting rooms for the urban poor" was one founder's phrase.

Heritage preservationists, as they – or we – are often called in the USA, are generally impatient with bleating about "property rights" heard from some developers whenever communities try to restrain the destruction of heritage or even excessive subdivision. Let us quickly put some historical context around this. Nineteenth century English property owners fought the first planning laws all the way to the Privy Council, just as some employers fought the Eight Hour Day, ship-owners mocked the introduction of the Plimsoll line, American landlords refused to build fire escapes, and slave-owners fought abolition.

Because the emergence of urban and regional planning as a practice and a profession was a reaction against the horrors of uncontrolled development, it is fair to say that modern and contemporary planning and its results— the towns and suburbs most of us now live in— are indirect and evolved products of the industrial revolution.

Coming back to the more specific works of engineers, it was the railways with their bridges and cuttings that were seen as the greatest destroyer of nature and rural scenery. Remember that at this time, especially pre-Darwin, Nature had literally divine status as God's handiwork which humanity should study and learn from, and there was widespread nostalgia for the fast-fading feudal traditions of rural life.

Mention of Darwin reminds us that the construction of railways also challenged the conventional religious beliefs about life on Earth and the age of the planet. It was during the excavation of railway cuttings that the best preserved and thus most influential dinosaur fossils were discovered. Geologists began to realise that the Earth was more than a few thousand years old, and that life forms had changed, and this inspired various scientific hypotheses including eventually Darwin and Wallace's Evolution by Natural Selection. The creationists, then the Christian mainstream rather than a rump as today, could suggest that God had faked the fossils and planted them to challenge our faith, but such notions became increasingly untenable.

Biblical literalists could regret the discovery of fossils in cuttings, but the strongest objection to railways in the landscape was that their alignments and bridges were an eyesore, and destroyed magnificent scenery. In the late 1850s, John Ruskin lamented:

"Wherever I look or travel in England or abroad, I see that men, wherever they can reach, destroy all beauty. They seem to have no other desire or hope but to have large houses and to be able to move fast. Every perfect spot which they can touch, they defile." He then gives a couple of examples in a footnote: "Thus, the railroad bridge over the Fall of Schaffhausen, and that round the Clarens shore of the Lake of Geneva, have destroyed the power of two pieces of scenery of which nothing can ever supply the place, in appeal to the higher ranks of European mind." (Modern Painters, volume IV, p329).

During the following decades, there were numerous campaigns, some more successful than others, to keep railways out of scenic places such as the Lake District. In the 20th century, as new highways took the place of new railways as the perceived destroyers of landscape aesthetics, the National Trust and other groups campaigned to limit their visual impact also. The architect Sir Herbert Baker whose massive building projects changed colonial landscapes in India and Africa, took a major role in a successful campaign to prevent ribbon development along English country roads and to limit the sprawl of rural villages. These controls have been of enormous benefit to the tourist industry in the UK, so I was horrified to discover, where I was last there in 2004, that the dark forces are still at it, lobbying for the abandonment of defined edges for rural villages, to encourage 'development'.

The Ruskinian perception of railways as destructive of landscape values had little resonance in 19th century Australia, presumably because the colonists (unlike the indigenous people) had no cultural attachment to a land which they found largely hostile. In Europe the view of railway works as destructive had to contend with the perception of them as heroic, but in Australia and even more in North America, the heroic interpretation carried the day. The heroic interpretation has never really been challenged in Australia, and now the time has come that we regard these bridges, like pumping stations and dam walls and old military sites, as items of historical importance, to be admired and protected as part of our heritage. In this sense, the idea of the engineer as landscape artist has retrospectively triumphed in our own time.

The most famous railway image in American art is *The Lackawanna Valley* of 1855 by George Inness, in the National Gallery in Washington DC. What image of railways in the landscape does it offer? You can see the artist is having a bet both ways. The large busy roundhouse and the speeding smoking train are pushed into the far and middle distance respectively. Closer to the artist's and thus the viewer's position is a watching figure reclining under the sole tree that has survived in the area. He is reminiscent of the "staffage", the shepherds or mythological figures in classical landscapes, who transmogrify into Aborigines in early Australian colonial landscapes. The observer within the painting does not seem to be distressed, and might be assumed to be favourably impressed, with the wonders of modern technology coming his way.

American art historians have generally seen this painting as expressing a positive attitude to railways in the landscape, quite the opposite of Ruskin's hatred. Perhaps they have been influenced by the fact that the painting was actually commissioned by the Lackawanna Railroad Corporation whose presence in Pennsylvania it depicts — even celebrates? I have stood and looked at this painting for a long time on several occasions over the last thirty years, and am always struck by the prominence in the foreground of the stumps of felled trees. The artist is emphasising that this area is cleared woodland. The railway is not shown to be the direct cause of this, unlike the mines and the woodlines that fed them were the cause of denudation (apparently temporary) of areas around many mines. But Ruskin, and Wordsworth whom he cited in this matter, would have been appalled by Inness's imagery, and seen it as recognition of the destruction expedited by the railways which inter alia supported and encouraged the conversion of forests to agricultural and other uses.

Most of us today would be depressed by the sight of these tree stumps. But if we project back in our own history, we can imagine another interpretation. We know only too well that in Australian political rhetoric, as in the works of our Heidelberg school artists, "clearing the land" was celebrated as economic and social progress. Streeton may have changed his tune later, but this ideology of "If it moves, shoot it; if it doesn't, chop it down" survived well into the 20th century, and still has its adherents. In populist politics, clearing the land was nation-building, it meant creating farms and homes for aspirational citizens, as for example in the often ill-fated group settlements in various parts of Australia in the post-World War One era. And although railway building had begun in Australia in the 1850s, the 1920s were its high-point all over that continent.

Whatever we think of some of the intended and unintended consequences, there is no denying that in O'Connor's time, engineers could be culture heroes. An example is John Whitton, a Yorkshireman who in 1852 at age 33 became I. K. Brunel's successor as Resident Engineer on the Oxford, Worcester and Wolverhampton Railway. In 1856 he was recruited as chief engineer of the New South Wales (NSW) Railways, and became known as "the man who conquered the mountains" in recognition of his greatest work: the railway across the great dividing range. Jim Haynes has written: "In the building of this railway, the colony truly came of age. No longer a quaint colonial backwater, the colony of NSW now had an engineering marvel to impress the world, along all the strange plants, animals and natural wonders."

Australia's most famous railway painting is Arthur Streeton's *Fire's On, Lapstone Tunnel* of 1891 in the Art Gallery of NSW. It does not actually depict a train, but shows an incident during the creation of a tunnel in the Blue Mountains, focusing on the drama, heroism and danger of railway building. The flurry of activity outside the tunnel mouth is because a man had just been killed in an explosion within. The tunnel mouth and associated workings are a wound in the landscape, the rest of which is depicted in Streeton's usual aestheticised style.

In closing this part of the talk, it can be noted that although we now admire many older engineering works as part of our heritage, new works can be controversial. The desire to preserve sensitive landscapes and habitats prevented the construction of certain proposed hydro-electric dams in Tasmania in the 1980s, and today there are fierce debates about the siting of wind-farms, and to the further expansion of industrial plants in the world's largest ancient rock art site — the Burrup Peninsula in north-western Australia.

3. REVISIONING THE LANDSCAPE

In 2007 I spoke to your previous conference in Perth about "The Engineer as Artist" so I am not proposing to tackle this theme in terms of the aesthetic qualities of engineers' designs, appreciating or critiqueing the shape and structural logic of the Eiffel Tower or the Sydney Harbour Bridge: that had been done a lot. Nor am I now looking into the work of engineers as architects, though they existed in most colonial societies, although that would make a good topic for another time. Today, we are investigating the idea that the works of the great engineers not only changed the appearance of the landscape and cityscape, but actually changed the way everyone else saw them, just as artists change the way we see the world by creating and imposing new images.

We see what we learn to see, and it is well established that the 19th century landscape painters, in Australia and elsewhere, showed people new and different ways of seeing the landscape, including drawing attention to aspects and places not previously much looked at or admired. Well known examples of this are J M W Turner's paintings of the European Alps, Eugen von Guerard in New Zealand and Australia, and local Impressionists everywhere who subsequently departed from the earlier colonial vision.

I mentioned the Eiffel Tower earlier, so will return to it very briefly to further explicate this theme. John Berger and Robert Hughes, among others, have discussed how this landmark edifice not only changed the look of Paris, but gave millions of people their first experience of a plan view of a city. Previously, this view had been available only to the very few who went up in hot-air balloons. Suddenly, the tower allowed people who had for years known the city only as a ground-level maze to actually see it laid out like a street map. The impact of this on art has been elaborated elsewhere, so I need not expound it here.

My argument is that engineers, through the impact of their work, were as influential as literary or visual artists in creating new imagery and evolving sense of place. The most obvious example of this, especially in Australia, is the experience of railway travel, which in the mid 19th century replaced horseback or stage coach. On or behind a horse, you covered only a few miles a day, with frequent stops to water or change horses, and for passengers to use dining and lavatory facilities at inns. On a train, you covered greater distances in a day, with long periods of continuous movement (and of course occasional stops for no apparent reason, in the middle of nowhere).

Even today, when we have air-conditioned fast cars and (sometimes) good highways, there is still a difference between the physical and visual experience of road and rail travel. Roads go up and over hills, imposing varying levels of effort on car engines and transmissions, so as a driver or passenger you are directly experiencing the rise and fall of the land. But because trains cannot climb steep hills, railway lines more often go through cuttings and embankments and tunnels on a relatively flat track. There are exceptions to this, especially in the past with such dramatic devices as the famous old zig-zag in the Blue Mountains, but it is a fair generalisation to say that roads go on the ground and trains go on, through and above it. A train passenger who is dozing or reading a book can go through mountains and over wide rivers without even noticing. One who looks out the window sees the land rise and fall while barrelling along without a bump or change of pace— insulated from the terrain, but seeing it and experiencing it aesthetically.

The contrast with pre-railway era road travel is extreme. In previous centuries, there had always been some road bridges, but these were limited in span. In most cases, when a stagecoach came to a river, there were two choices. Put it on a barge or punt, and ferry it across; or unload everyone and everything, put them on a boat, and then onto another coach when the river was crossed. This was time consuming, and slowed the journey down greatly. It also meant that the travellers experienced the river crossing as a quite different affair from the on-road travelling, although both could be equally rough and jolting.

But with railways, once the huge investment had been made in engineering works, formerly impassable barriers were flown over, often without a change of pace. Crossing a river several hundred metres wide could add an hour or two to a coach journey; but a train on a steel bridge was across it in a minute or less. This is not just about speed, or the perception of speed which has pre-occupied many writers about the way early railways were experienced — it is about the homogenising and smoothing of the travel experience across varied terrain.

As well as speed, the traveller's isolation from the surrounding landscape was heightened by the side-effects of the technology, especially when viewed from outside. At times, the train passed in a blur of speed, and at times it was wrapped in a steam and smoke cloud of its own making. The most famous image of this is J M W Turner's *Rain, Speed and Steam*.

Ruskin claimed that fast train travel was not really travel at all: you were just being sent like a parcel from one place to another without actually experiencing the places you passed through. I am taking a different line, and suggesting that you may experience the places en route, but in a different way: more visual and less physically interactive. It might be taken as a variant of that cultural studies cliché "the tourist gaze".

Ruskin also objected to railways because much of the travel they facilitated was, in his opinion, to no good purpose. To paraphrase and generalise one of his famous grumpy remarks, he said that the train made it possible for every fool in the suburbs to be in town in 20 minutes, and for every fool from the town to be in the suburbs. Which leads us to tourism, and on to the way engineering projects changed the relationship, and in a sense the relative location as well as the identity, of places.

4. CHANGING THE RELATION OF PLACES

Railways, and also the new large iron steam-powered ships pioneered by super-engineer Ismbard Kingdom Brunel, permitted the rise of popular tourism for the middle classes. It was of course Thomas Cook who realised the potential of railways and steamers to cheaply, reliably and regularly move large numbers of people together, so he invented the package tour. It took another century until we got jumbo jets and other planes big enough for mass tourism to take to the air.

Mass train travel, and the safe operation of railways in general, required a structured system of time. Until the mid-19th century, local time ruled everywhere and there was no consistency. The need to schedule trains was the chief motivation of the development of standardised time as we know it, and the redrawing of national and international maps into time zones which transcend political boundaries.

Once large numbers of people can and do travel, we perceive the world as smaller, and exotic places as closer. When we hear of a civil war in Sri Lanka or a terrorist atrocity in Indonesia, many of us know the places where it is happening and identify with it to a degree once unimaginable.

Transport links and their components such as bridges and tunnels, but also pipelines whether for water or fuel, change the relationship of places. We can obtain, and worry about depending upon, supplies of all sorts from far away. On an Australian farm in the first half of the 19th century, if you needed a piece of furniture urgently, you made it yourself, or found a local craftsman. By the end of the 19th century, you looked in a catalogue (delivered by mail, most of the way on a train) and ordered what you want, which was then sent out (again, most of the way by train) a few days later.

The big change in the time taken to transport goods overland occurred with trains. In the 1850s, my great-grandfather paid off his farm in the Clare Valley in South Australia by operating a bullock dray carrier service between Clare and Adelaide. A round trip took him three weeks. When the railway was built, the train trip took six to eight hours each way. Today, a car or delivery truck does the one-way trip by road in two or three hours. The gap between that and the time taken by the train, is very much less than the gap between the train's time and great-grandfather's bullock dray. Similarly, in Western Australia where I now live, the completion of the railway moved Kalgoorlie closer to Perth, by a greater margin than it was later moved closer again by the introduction of air services.

The cultural map of our countries was shaped by the distribution of technologies. As another South Australian example, the Barossa Valley, settled by German immigrants in the 1850s, remained a centre of Germanic traditional arts and crafts well into the 20th century. In fact, traditional styles survived there long after they had gone out of fashion in the Fatherland. Art historians attribute this to the fact that the railway did not go through to the Barossa until the first decade of the 20th century, so those communities remained relatively isolated and self-sufficient, hardly affected by changes in fashion in the cities and other regions.

Ruskin had seen what was happening from the very start, and understood that the changes were cultural, not merely functional: 'The iron roads are tearing up the surface of Europe;.. their great net is drawing and twitching the ancient frame and strength together, contracting all its various life, its rocky arm and rural heart, into a narrow, finite, calculating metropolis of manufactures." (Modern Painters, II, p6)

5. REDRAWING THE POLITICAL MAP AND CONQUERING THE WORLD

Many great engineering projects were undertaken for political reasons. Both at the time, and in historical retrospect, a government's sponsorship of infrastructure is often cited as a measure of its historical importance. Failure to undertake necessary or beneficial projects is commonly taken as indicative of weakness, waste of opportunities, and irrelevance.

Governments which spend millions, or these days billions, on vast engineering projects must be sure they will keep control of them in the future. The creation of large-scale engineering works is only possible if you have political control of the place and the resources; and when completed, the existence of the infrastructure demands continuing or even increased control. Dams, railways, electricity supply, pipelines (think of oil in the middle east and Russia) and harbours are perceived as obvious targets for strikers, rogue capitalists, and terrorists. The need to maintain control over engineering infrastructure both in the building and operational phases has often led to re-drawing of the political map. The most celebrated examples of this have been shipping canals. De Lesseps built the Suez Canal and the French Empress Eugenie officially opened it in 1867, and for the next ninety years at least it was the focus of political manipulations and even wars between Egypt, England, and other powers.

The extreme case of re-drawing the political map involves the far more expensive and ambitious Panama Canal. De Lesseps and others tried but failed to build a sea-level canal through Nicaragua or Colombia. In 1903, the USA stepped in, as they wanted to be able to move their navy between their east and west coasts, and control inter-oceanic traffic. US interests funded the canal, and to secure it fomented war and revolution to create the breakaway nation-state of Panama, with a Canal Zone which remained US-controlled until very recently.

In O'Connor's case, the Forrest government's support for the Pipeline was motivated largely by the need to lock the economically important goldfields into the colony and state of WA. In the lead-up to federation, there was talk of secession and a new state of "Aurelia". The colonial government built the Pipeline and the railway, and thereafter the goldfields were literally tied to Perth and Fremantle, and connections with Esperance diminished. At the next level up, the participation of WA in the newly federated nation of Australia was secured by the commitment to build the transcontinental railway which functionally, and visibly on the maps, tied the west to the east.

At the start of the 21st century, in Australia we are seeing political claim and counterclaim as the eastern states and the Commonwealth restructure control of the Murray River system; and everywhere there are tensions as cities come to increasingly depend on water from rural areas. From time to time (usually at election times) politicians propose grand new engineering schemes such as canals or more pipelines to move fresh water, and we even hear of proposals for "reverse pipelines" to remove salty ground water from agricultural regions affected by salinity.

If today's politicians are more hesitant than John Forrest or Teddy Roosevelt to embark on grand engineering schemes to solve specific problems, it may be because we have learnt a few lessons over the last hundred years. Some of the impressive, and indeed successful, schemes of the past have had unintended consequences, solving problems in one place but creating problems elsewhere. Obvious examples include salinity and loss of habitat due to deforestation and over-irrigation in Australia, and there are human and environmental disaster stories world-wide associated with oil pipelines, high dams, nuclear meltdowns, pollution and toxicity, etcetera, etcetera.

In the heroic era of engineering, there was insufficient understanding of the interconnectedness of ecosystems. There was often also scant concern for minorities and indigenous peoples. It needs to be recognised that some scientists and conservationists were issuing warnings at that time, but they were barely heard in the populist clamour for progress and problem-solving. The failure of understanding is encapsulated in the essay *The Moral Equivalent of War* by US philosopher William James. This essay was not published until the year of his death, 1910, but he had been influential for many decades previously.

The main theme of James's argument is commendable, inasmuch as he called upon governments of all nations to eschew fighting each other, and instead jointly pursue grand and often dangerous civil endeavours. He wanted to engage the energy of youth and the skills of the experienced to exploit the resources of the world, to raise standards of living everywhere. As well as fishing fleets and mining, he cited the building of roads, tunnels, canals and skyscrapers. To achieve this concentration of effort, he advocated a form of civil conscription, instead of putting young people into the military, hence "the moral equivalent of war".

The problem in James's formulation is that he sees these grand endeavours as "a war against nature", a better activity than war against other peoples. James and many others of his time had a Darwinian view of the world and nature as fundamentally hostile to the human struggle for survival and progress. Rather than thinking in terms of working with nature, they saw nature as an enemy to be conquered, and gave little thought to the possibilities for collateral damage to the environment and society.

Two years later, in 1912, the imperialist geographer Dr Marion Newbigin reviewed the achievements of the 19th century and earlier times in a book tellingly entitled *Man and his Conquest of Nature.* Newbigin used similar aggressive language, referring to: "man's age-long struggle with Nature,,, to render permanent his hold upon shifting Nature…. His modes of attack upon Nature have been as manifold as is Nature herself, and everywhere the fortunes of the fight have varied with the natural conditions."

Robert Stafford has described the popular late 19th and early 20th century view of the world as consisting of: "undisciplined nature, uncivilised peoples, primitiveness, limitlessness, and bizarre extremes. Implicit in the challenge of these strange continents, however, lay opportunity, excitement, the illusion of infinite resources, exotic fields for personal and national expression. The disposition… was aggressively interventionist. While the scientists often expressed regret at the destruction of native peoples and natural environments, the majority viewed this process as inevitable, and the European right to drastic modification of peoples, species, and entire biotas as unquestionable".

There was even an interplanetary example of the alleged ability of intelligent beings to change whole worlds and defy climate change: the greatest scientific myth of all time, the Canals of Mars. Linear markings observed on Mars were widely believed, between 1895 and the1920s, to be a vast network of artificial canals bringing water from the melting polar caps to the pitiless deserts which comprise most of its surface. This implied a great global project only possible if there was a unified polity and no wars. This interpretation (based on extrapolation from faulty astronomic observations) was wrong, but it was then widely believed including by many eminent scientists, and was enormously influential.

We now know that the map and the view of Mars was not created by a race of older wiser canal-building Martian pacifists, but I hope I have shown some of the various ways in which the great Earthly engineers of the late 19th and early 20th centuries changed the view, understanding, and indeed the map of our planet. O'Connor and his peers deserve our respect, and their work deserves to be preserved as our heritage. We are going to need some more great engineers and brave politicians if we are to survive on Earth, and the lesson we must learn from the successes and failures of O'Connor's era is that we must not think in terms of War against Nature, but of working with nature and the highest cultural values.

Heritage Management at the Port Craig Sawmill Complex: Successes and Challenges.

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SUMMARY: *The Port Craig sawmill, Te Waewae Bay, Southland, was the most technologically advanced sawmill in 1920s New Zealand, and one of the most ambitious sawmilling enterprises in NZ history, using high-output hauling and milling equipment from the United States of America. Today it is a heritage site including some intact original structures and a range of archaeological features, representing all elements of the early twentieth century timber milling industry in NZ. Successes in management to date have relied upon limited budgets, and the good will and hard work of the local community. The challenges that lie ahead require more money and support than that community can provide. The entire site is of national, if not international significance. This needs to be acknowledged and promoted to achieve the conservation of key features, to access the funding required, and draw the visitor numbers that will help sustain the area into the future.*

1. INTRODUCTION

Port Craig is located on the western side of Te Waewae Bay, western Southland. It is set amongst regenerating lowland coastal mixed podocarp forest. The former sawmill and settlement site is on land managed by the Department of Conservation (DOC), formerly Waitutu State Forest, and now part of Fiordland National Park. The sawmill tramway roughly follows the alignment of a surveyed road through Maori land to the west of the mill site. The bulk of the sawmill workings, including branch tramlines and log hauler sites, were also located within this Maori land. The nearest town is Tuatapere, which sprang up around the turn of the last century to service the large number of sawmills that were progressing through the surrounding forests.

Figure 1. *Foveaux Strait showing the site location. (Land Information NZ, 1997, NZMS 262-16 Invercargill.)*

2. HISTORY

The history of Port Craig has been well researched and recounted by Warren Bird, in his book *Viaducts Against the Sky*.[1] Some earlier work compliments Bird's publication. Mark Hanger's research for the New Zealand Forest Service in the 1980s[2] provides a good overview of most of the Southland sawmills including Port Craig, and offers context and comparisons. Alistair McMechan's university thesis[3] explores the enterprise from an academic history perspective. More recently Michael Kelly has synthesised these and a range of other sources for a conservation plan for the Port Craig viaducts[4] and a registration report[5] for the New Zealand Historic Places Trust (NZHPT). The account that follows draws heavily upon these sources, and is only a very brief summary.

2.1 Marlborough Timber Company

The Marlborough Timber Company (MTC) began operations at Nydia Bay, Marlborough Sounds in 1908, and progressed on to mill in the Opouri Valley. Through good management and selection of a good logging area the company became relatively wealthy and successful.

By 1914 they had worked out the millable areas available to them in the valley, and were eager to take the company to a new level through the introduction of large scale logging technology from the USA.[6] Daniel Reese, one of the company directors, had visited the USA and been impressed with the logging technology. Paul Mahoney notes it is also possible he had seen it in action in NZ as the company's main competitor in the Opouri Valley, Brownlee, was using North American technology.[7] John Craig, the manager of the Marlborough based milling, and a company director, shared Reese's interest in the technology.[8] The other directors agreed to send Craig to see it in operation in the USA, and the visit further convinced him its application in New Zealand forests would bring great benefits to the company. Craig's enthusiasm soon won the idea the support of the whole directorate and a search began for a forest that could sustain the hungry technology. Criteria for a suitable area were that the forest available have high yielding trees, be extensive enough to sustain the mill for many years to come to offset the relatively high costs of establishment; and that it have easy accessibility for the shipment of the timber and yet be isolated enough that other companies would be unlikely to move in and compete.[9] It was also important that the new area allowed the company to get around the size restrictions of State Forest licensing.[10]

2.2 State Forest management

Government control of logging from the 1870s through to the 1920s was characterised by a tightening of regulations, and increasing restrictions on the size of milling operations. Perceptions of forest as an inexhaustible resource and an enemy of progress were gradually re-framed as concerns arose about a looming timber famine. The Government approach was to slow the rate of logging and manage forests to ensure they could be harvested in the future, and there was a move to set aside areas for conservation in perpetuity in the form of reserves and national parks. From the early 1900s there were regulations to prevent monopolies over large tracts of State Forest, and a restriction on the size of licence areas to no more than three times the annual capacity of the associated mill. The government promoted smaller milling operations, and there was what some historians have termed an 'anti-big business' approach. Finally the State Forest Service was created to administer government control of State Forests, in 1921.[11]

2.3 Mussel Beach and South Island Landless Native Act lands

After investigating a few alternatives the MTC settled upon Mussel Beach at the western edge of Te Waewae bay, now known as Port Craig, as the best alternative. Among the greatest benefits of the location, along with the seemingly plentiful forests, was the proximity to large tracts of Maori land, and the opportunity this presented to overcome State Forest licensing restrictions. Bird gives the Mohaka River in Hawke Bay as one of the alternative locations investigated,[12] and it is interesting to note that there are extensive areas of Maori land there as well.[13] Bird indicates that this location was ruled out because of the other milling operations in the area.[14]

The Maori land upon which MTC set its sights had been allocated under the South Island Landless Natives Act (SILNA) 1906, the owners of which held little prospect of earning a livelihood from their isolated sections. It is hardly surprising then, that by the time the mill at Mussel Beach had been fully established the company had successfully negotiated cutting rights to 4000 acres, much of which was SILNA land.[15] The owners of only two sections between Mussel Beach and the Wairaurahiri River declined to sell cutting rights to the company.[16] The Forestry Department was concerned that the price paid to the SILNA owners should be equivalent to the going rate for State Forest licences, not only to protect the interests of those owners, but also to ensure that the surrounding State Forest was not devalued, and recommended a rate of £5 per acre.[17] A survey undertaken on behalf of the Maori owners in the same year indicated that the initial estimates of forest yield were too high at 20,000 superficial feet per acre, and estimated them to be closer to 10,000. The price negotiated was therefore at a lower rate of between £2/10/- and £2/15/-.[18]

2.4 Establishment at Port Craig

Whilst the company awaited the arrival of the new milling plant from the Sumner Iron Works, Everett, Washington State, USA, work proceeded to develop the mill and settlement facilities at Mussel Beach from late in 1916. One of the company's mill plants was relocated from Marlborough to provide timber for construction of mill buildings and worker accommodation in 1917.

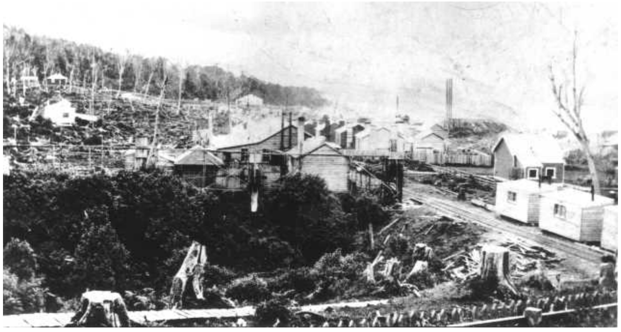

Figure 2. *Port Craig settlement at its peak. (NZ Forest Service photograph collection, copies held by Department of Conservation.)*

Among the other tasks that had to be completed at the outset was the construction of a breakwater (at immense cost) to shelter the wharf.[19] It was during the erection of the mill plant from Opouri that John Craig was killed in a drowning accident, and the mill and town were then named in his memory.[20] The building for the new mill equipment was constructed by a company builder, the installation of the equipment was overseen by representatives of Sumner Iron Works, and the mill was opened to great fanfare in September 1921. By this time all the worker accommodation, a cookhouse, company store, billiard room, social hall, library, and school had been constructed. The outlay of capital must have been extraordinary, and it is hardly surprising that by 1924 the company was struggling financially and took a major investment by Sims Cooper and Company to remain afloat.[21]

2.5 Lidgerwood Log Hauler

For the mill plant to reach optimum operating capacity it required a huge input of logs, far greater than could be efficiently supplied by conventional NZ log hauler technology. The eighty tonne Lidgerwood Overhead Logging Plant, an American-built log hauler, was the largest and most sophisticated hauler in NZ at the time the MTC imported it in 1918. It could haul logs on multiple lines, from up to 800 metres, and once in position could operate on a 360° spectrum with the relocation of the spar.[22] Forest Department files on the mill licences comment that the reach of the Lidgerwood was twice that of its contemporaries, and that it would need licence areas of double the regulation size of 200 acres to operate effectively.[23]

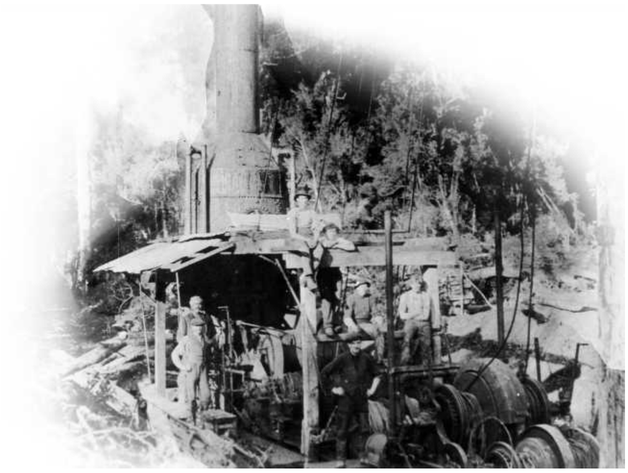

Figure 3 *The Lidgerwood Overhead Logging Plant. (NZ Forest Service photograph collection, copies held by Department of Conservation.)*

The Lidgerwood had the potential to extract logs from an area more quickly and efficiently than any other log haulers being used in NZ. However, the complex and expensive rigging system required specialist operators who had to be trained and while the forest at Port Craig was of high quality, the lower than estimated density of millable trees meant that the hauler had to be moved too frequently and a lot of time was spent relocating it, making it inefficient. As a consequence when the U.S. manufactured boiler failed, the construction not being as durable as those made in NZ, it was not economic to refurbish it.[24] During its operation the Lidgerwood was never able to supply the amount of timber required to operate the mill plant at its maximum capacity because of the lower than estimated forest density. In fact the highest monthly output ever achieved by the mill was 1814 cubic metres in May 1928, after the Lidgerwood had been mothballed, was still some way short of its capacity.[25] Four smaller NZ manufactured haulers were introduced to take its place, supplementing an existing three others, and together these were used for most of the logging beyond Percy Burn.[26] The decision was a wise one, for when the timber lots at the Wairaurahiri end of the tramline were resurveyed in around1925-26 it was estimated that there was only 6-7,000 superficial feet of timber to the acre- a third of the original estimates.[27]

2.6 Tram lines

The construction of tramlines was an extremely costly component in the infrastructure establishment.[28] Sawmill tramlines were generally built to a standard which reflected their fleeting utility. However, at Port Craig the MTC had a long term vision of logging for years, or even decades, over the many thousands of hectares of forest that lie to the west. They also needed a line durable enough to carry the weight of the eighty tonne Lidgerwood overhead log hauler, by far the heaviest equipment that had to travel the rail. For these reasons they invested heavily in building a very high standard of tramline with a 3’6” gauge – the same as NZ Railways – on squared hardwood sleepers, over a total distance of 14.6 kilometres. The additional 9.8 kilometres of branch tramlines were built to a slightly lower standard, with less finished timbers, but still at a higher standard than was normal for contemporary logging operations. For the most part the tramway roughly follows the route of a legal road alignment surveyed in 1901 as part of the survey of the SILNA blocks. However, it is seldom exactly on the surveyed line, and in some places it deviates dramatically to find terrain that more easily accommodates a suitable gradient, or in the approaches to a gully where a viaduct was required.

Figure 4. *A section of tram line during use. (NZ Forest Service photograph collection, copies held by Department of Conservation.)*

2.7 Viaducts

The construction of large timber viaducts enabled the tramway to cross four steep stream gullies without a change in gradient, avoiding many extra kilometres of benched tramline that would have otherwise been required to navigate the gullies.[29] Like the tramway, the specifications of the viaducts had to take into account the weight of the Lidgerwood Overhead Logging Plant, as well as the varying terrain of each gully and this is reflected in the characteristics of each viaduct. The exact timing of viaduct construction is not recorded. It is known that the tramway had reached the first, Sand Hill Point, by 1924, but construction may have commenced in advance of the tramway. The second and largest viaduct, Percy Burn, was completed in 1925 and reduced the builder, Chester Construction Company, to bankruptcy. The completion date for the third and fourth, Edwin Burn and Francis Burn, are not known either but it is likely that it was before 1926. Sand Hill, Francis Burn and Edwin Burn were built by Jim Kane, a former NZ Railways bridge builder, and a team of Company workers.[30]

Figure 5. *Percy Burn Viaduct. (Crown Copyright: Department of Conservation, Te Papa Atawhai, Photographer: Wayne Baxter.)*

2.8 Economic failure

Despite the investment of unprecedented levels of capital (or perhaps because of it) the mill struggled to make a profit.[31] Aside from a decline in timber demand and a steady drop in timber prices, in hindsight it is clear that the operation was capitalised to a level far in excess of the return the forest could provide, especially when it is taken into account that the forest yield was only half to a third of what had been estimated. In addition the operation seemed to be beset with expensive challenges, like the failure of the Lidgerwood overhead hauler, which required the investment of more capital. Another example is the effect of the breakwater which allowed the build-up of sand on the formerly rocky mussel beach, reducing the draft available at the wharf so much that it was not possible to berth there much of the time. This made it necessary to use shallow drafted lighters to transfer timber from the wharf to vessels anchored in the bay. This slowed the loading rate, added to transport costs, and further reduced the dwindling profit margins of the company.[32]

The innovative engineering solution, unsurprisingly based on an idea from the USA, was to implement an aerial loading system. This involved an extension to the wharf, construction of a substantial tower at the end, a series of permanent anchors and moorings for anchoring ships, and a complex web of cables that were used to load the timber. When working to its full capability the loading system was the fastest in the country, but it was not a sufficient panacea to save the mill.[33]

Finally in late 1928 the directors of the company made the very difficult decision to withdraw, and the operation was closed immediately with minimal notice to workers. Shortly afterwards Holdings Limited was set up by Sims Cooper, who had invested substantially in the operations, to take over the liquidated assets of MTC. Holdings Limited employed a small staff of caretakers to protect the assets, and made a successful application to take over the mill and tramway licences formerly held by MTC, based on hopes they could revive the operation and recoup some of the establishment costs.[34] In its final months the MTC had applied for a new licence area in the State Forest to the north of the SILNA lands, on the Francis Burn.[35] This was probably done knowing there was no way to raise the capital to cross the Wairaurahiri River, and this was the only means of accessing new forest. Holdings Limited took over the licence for this area as well and continued to renew all licences from 1928 until 1941. There was a brief revival of the milling operation during 1930, but the effects of the great Depression on timber markets doomed the attempt to failure. In 1938 a team was sent to salvage as much as possible, and demolish the remainder.[36] Finally in 1941 the Forest Service refused the last application to renew the licences, the Director of Forestry stating in his report *...I feel, however, that the Service has 'nursed' the Company long enough, and that the time has arrived when some action should be taken to terminate these rights.*[37]

3. SITE MANAGEMENT

Over the past fifteen years Port Craig has been regaining economic importance as a recreation and tourist attraction. This has been in no small part a result of the development of the Hump Ridge Track by the Tuatapere community, which has involved the construction of a new section of track up to the tops, creating a three day loop walk off the South Coast Track. The track development has been part of wider efforts to develop a new economic foundation for the town in tourism (beginning with the "Southern Scenic Route" promotion in the 1980s) in the wake of the decline in the native timber industry and the demise of the NZ Forest Service in 1987. Heritage values have been a key element of the visitor attraction at Port Craig and for the Hump Ridge Track, and there has been ongoing work to conserve and manage the features of the site complex by all the agencies and organisations involved.

3.1 Southland's Port Craig Viaducts Charitable Trust

Southland's Port Craig Viaducts Charitable Trust manages the four impressive timber viaducts with the support of the Southland District Council (SDC), Venture Southland, DOC, and NZHPT. The astounding efforts of the Tuatapere community from 1994 to raise funds for work on the Percy Burn viaduct are well known. The Trust has also been instrumental in subsequent projects to undertake further repair work on Percy Burn and the other viaducts. Trevor Butler's paper in these proceedings explores the work on the viaducts in more detail. The paragraphs that follow focus instead on work that DOC has undertaken in managing the other components of the site: the tramway, sawmill and settlement site, and school.

3.2 Sawmill, settlement and school

The sawmill and settlement complex, including buildings, structures and archaeological features, is one of 73 sites on Public Conservation Land in Southland Conservancy that were identified for active management in 1991, because of their historic significance.

Figure 6. *Port Craig School today. (Crown Copyright: Department of Conservation, Te Papa Atawhai, 2008, Photographer: Rachael Egerton.)*

The school has a Category II NZHPT registration, is the most intact feature at the settlement site, and is also managed as a back country hut. A conservation plan for the building was prepared in 1992 by Chris Cochran.[38] Since then work on the school has included: re-piling, repairs to and re-pointing of the chimney, reinstatement of missing weatherboards and replacement of rotten ones, regular repainting, and the reinstatement of a lookalike water tank exterior to match the one shown in historic pictures of the building. Visitor and safety enhancements have also been undertaken. The open fireplace has been boarded up and a log burner, common in DOC huts, has been put in using the original chimney to house the flue. New stainless steel sink benches are in place, and part of the entranceway has been walled off to create a storage room.

In 1996 an archaeological survey of the saw mill and settlement site was undertaken by Jackie Breen, on contract to DOC. This was done to improve knowledge of the remaining site features so that their conservation might be better prioritised and planned for. A secondary reason was to provide sufficient information to guide the careful placement of any future visitor facilities, as by this time planning for the Hump Ridge Track was under way, and the Hump Ridge Track Trust was keen to locate new accommodation at Port Craig. A hut for Hump Ridge Track walkers has since been located within the former settlement. The survey revealed archaeological remains of every aspect of the mill and settlement, showing Port Craig to be an extensive heritage landscape.[39]

Following the archaeological survey a specification for conservation work was developed for the range of features identified. Varying levels of intervention were recommended and have been completed. For some features no action will be taken, for others simple vegetation control is specified, and for a few a higher level of work is required to ensure conservation into the future. Some of the large timber piles and beams that once supported the timber sorting tables at the beach still remain, and timber preservatives are being used here to arrest the process of decay. The Priestman crane used on the wharf for loading timber was dug out of thick alluvial beach gravels over a period of years by conservation volunteers, with the bulk of the work being completed by Paul Clements with some of his Fire Service colleagues from Dunedin. Clements has also been instrumental in raising the chassis of the famous Lidgerwood overhead log hauler onto timber foundations, and metal preservation regimes are being implemented here. A large amount of vegetation removal and ongoing control has also been undertaken to ensure the conservation of these and other features around the site.

Figure 7. *Baker's oven after completion of conservation work. (Crown Copyright: Department of Conservation, Te Papa Atawhai, 2005)*

There are a number of brick structures including the baker's oven; domestic fireplaces and partial chimneys at the bush boss and mill manager's houses, and the boiler housing at the first mill site (where the mill plant from Opouri was installed). A specialist conservation work specification to repair these was prepared by Ian Bowman in 2001 and the work was completed in 2005 using national funding.

An interpretative walk has been developed to provide visitors with an opportunity to view the durable site features. There are some information panels, but most of the information is provided in a pamphlet. This is complimented by panels and flip-books in the Port Craig School, and the Hump Ridge Track facilities at Port Craig. The interpretation prepared by Cathy Macfie in 2004 greatly enhances the visitor experience at the site, and the walk allows access to key features whilst drawing people away from more delicate parts of the site.

Figure 8. *Interpretation panel at the Lidgerwood chassis on the interpretative walk at Port Craig. (Crown Copyright: Department of Conservation, Te Papa Atawhai, 2005, Photographer: Rachael Egerton.)*

3.3 Tramway

Incremental work is being done to remove the leaf litter and soil build up in the water tables and in the cuttings of the tramway that leads away from the mill site to the mill workings, and which is now used by walkers of the South Coast and Hump Ridge tracks. This is more challenging work, because of the scale of the task and the very monotonous back-breaking nature of the labour. Sections of this have been done by Alliance Freezing Works employees, but also by volunteers on Conservation Volunteer Programme trips, and by DOC staff. During the winter of 2009 a trial was done in one of the cuttings to remove all the trees which were growing in the cutting wall, and on the upper berm of the cutting wall. It is recognised that although they are stable now, cutting walls will begin to fail as the trees get larger, and their weight and gravity combine to cause them to pull away large sections. The current goal is to target a few good examples of cuttings and undertake similar vegetation removal in coming years.

Figure 9. *A section of the Port Craig tram line during the removal of trees growing on the cutting. (Crown Copyright: Department of Conservation, Te Papa Atawhai, 2009, Photographer: Keri Tuna.)*

4. SITE SIGNIFICANCE

The Percy Burn viaduct, the best known feature of the site, is nationally significant in its own right, with IPENZ recognition and Category I NZHPT registration. The school has Category II registration recognising its national significance. However, the importance of the site as a whole is far greater than the sum of its parts. The significance of the Port Craig complex stems, in part, from the fact that it represents all aspects of early 20th century sawmilling and associated settlement, either as archaeological features and ruins or intact structures. Because pastoral development followed in the wake of much NZ timber milling, and the equipment and plant were usually removed to the next logging location, only a few sites retain this level of integrity. While the mill was typical in many ways, the history outlined above highlights that it was also exceptional. The big business and long term, large scale capital investment approach to the operation, the innovative solutions developed to meet the engineering challenges at the site, and the use of large scale US logging technology in many aspects of the operation all set Port Craig apart. These aspects of the history are represented at the site by features such as the Lidgerwood chassis and boiler, the tramway, and the four viaducts.

It is only by looking at all the components together that the overall significance of the site can be appreciated. Management has involved the respective agencies working together over the years, but the challenges ahead for the conservation of the site, particularly the viaducts and the tramway, mean management needs to become even more integrated and promotion of the significance of the site as a whole will be necessary.

5. CHALLENGES

Management has presented a number of challenges over the years, not least of which is the difficulty of working on structures on the scale of the viaducts in such an isolated location. In spite of the monumental efforts of the Tuatapere community they have only been able to just keep ahead of the most urgent repair work, and there has been no ability to move on to a rigorous regular maintenance programme. The lack of maintenance means that timber decay has proceeded unchecked, and this has precipitated some of the more recent repair works to the viaducts, as well as the repair work that is currently required.

A number of factors have contributed to this situation. Partly it is a result of the relative difficulty there is in obtaining funding for ongoing maintenance for heritage, compared to gaining funds for one-off repairs. This is a wide spread problem. The absence of a single conservation plan for all four viaducts, identifying all repairs required, and prescribing an ongoing maintenance programme has meant that this work has never been outlined, quantified, and prioritised into a work programme. Furthermore the management of the viaducts is an enormous expectation to place upon a community the size of Tuatapere. During the lifetime of Southland's Port Craig Viaducts Charitable Trust a large number of its members have passed away and not been replaced. Many of them have joined the Hump Ridge Track Trust to provide a marketable experience to go with the viaducts. It is an understatement to say that they are stretched very thinly.

The challenge of managing the tramway is slightly different. Agreements have been made with the owners of a number of the SILNA blocks by DOC to undertake track maintenance and by the Hump Ridge Track to allow for of its use by walkers. Annual budgets are sufficient to maintain a back country walking track. However, the maintenance standards required for a tramping track are far less than those required to ensure the ongoing conservation of the tramway features – the very things that give the walk its character. Although the DOC has budgets for heritage management, they are very meagre. The work done at the saw mill and settlement, and the little which has been done on the tramway so far has been spread over a seventeen year period and has relied heavily on the efforts of volunteers. The cost and hours required to complete the work on the tramway are probably far in excess of all the work already achieved, and at current funding levels it is likely to stretch out for decades. The tramway is not suffering the immediate consequences of a lack of maintenance, but this will change before long as the features like cutting walls are broken down by tree falls. Bids for extra national funding to accelerate this work have been unsuccessful to date, as the same situation is faced at many nationally significant sites all around the country, some in even more dire circumstances.

6. STEPS TOWARDS THE FUTURE

Southland's Port Craig Viaducts Charitable Trust recently commissioned a conservation plan to identify ongoing management requirements of the viaducts, and establish a programme of repair and maintenance. This has been prepared by Chris Cochran, Trevor Butler (Frame Group), Michael Kelly, and Russell Murray. It was funded in part by a Lotteries Board grant, and partly by SDC and DOC. It quantifies the scale of the work required not just to repair, but also to maintain the viaducts so that ongoing deterioration can be minimised.

Figure 10. *Sir Neil Cossons, former chair of English Heritage, a great enthusiast of industrial heritage was very impressed with his Port Craig experience. Shown at the brick boiler housing of the first mill. (Crown Copyright: Department of Conservation, Te Papa Atawhai, 2007, Photographer: Brian Murphy.)*

The work required is no less daunting than all that has been achieved already, and will require substantial injections of finance, not only to address repair works, but to sustain the programme of ongoing annual maintenance. Such knowledge and planning are necessary for the fundraising challenge ahead and to ensure that the management approach is well informed and realistic.

However, good planning alone will not be enough. The levels of funding that are required are such that the outstanding national significance of the site as a whole will need to be acknowledged and promoted, so that fundraising can be undertaken at a national level. To assist with this the NZHPT have been reviewing the existing registrations, and a nomination report has been prepared by Michael Kelly for registration of the whole site as an historic place including the mill and settlement remains, the tramway and branch lines, as well as all four viaducts and the school. The registration process is now reached the stage of consultation with the SILNA land owners. After over 100 years of struggling to get very little benefit from their land allocations there is an understandable reluctance amongst the land owners to support registration which has much perceived if not real potential to 'encumber' their land use in the future. Better understanding the concerns of the SILNA owners, helping them understand the effects and benefits of registration for the heritage and the potential benefits for the area, and coming to an agreed way forward for registration will take some time. It will also be necessary to strengthen the presence of the SILNA land in the telling of the Port Craig story. International recognition for the site may also be necessary to lift the fundraising potential, but this is an idea yet to be investigated. Lifting the national recognition of the site will also greatly improve the possibility of DOC obtaining sufficient funding to undertake the work required on the tramway.

While the Tuatapere community has put in exceptional level of effort over the years, the author believes the national significance of the site makes it a national responsibility. A publicity and marketing plan will need to be developed to maximise the benefits of national significance, and take support for the cause of conservation of the site to a wider, national audience. To do this there needs to be a greater demonstration of integrated management, and all the stakeholders need to work very closely together. Finally there is a need for a rejuvenation of the Viaducts Trust. The Trust has already begun to seek new trustees, and is looking to have a high profile figure on their trust board. It is also important that the trust has the support of qualified and experienced heritage professionals, including engineers, either as members or as "friends" of the Trust, to ensure that they have the expertise and guidance to support their implementation of the conservation plan. It is likely that some of this support will have to come from outside Southland.

Above all there is a real need for all the parties who have an interest in the area, including the Tuatapere Community and the SILNA land owners, to work more closely together on their common goals.

7. CONCLUSIONS

Profiling the national significance of the whole Port Craig site is a key step to obtaining funding and support for the conservation of the viaducts, tramway, sawmill, settlement and school. To achieve this it will be essential to adopt a more integrated management approach involving all interested parties. Raising the national and international profile of the heritage and natural values of the area ultimately has the potential to increase visitor numbers, and bring economic benefits to the province, the local community, and the landowners, as well as ensure the heritage values are conserved into the future.

8. ACKNOWLEDGMENTS

Thanks are due to Department of Conservation, Southland's Port Craig Viaducts Charitable Trust, the Tuatapere community, Venture Southland, Southland District Council, New Zealand Historic Places Trust, SILNA landowners and Archives New Zealand, as well as all those who have made history at Port Craig or dedicated their time to preserving it – either through research and writing, or with shovels, chainsaws, hammers and preservatives.

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[18] Hanger, section VI: Port Craig. The Bush.

[19] McMechan, p.18.

[20] Kelly, p.9.

[21] Ibid., pp.9-10. The school built by the company was located at the beach. As the mill got into full swing this location became unsuitable, being surrounded by stacked timber and subject to flooding during high tides. In 1926 the Southland Education Board built a new school, the one which remains today, up on the terrace in the settlement.

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History of Auckland Wastewater and Mangere Wastewater Treatment Plant

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SUMMARY: *This paper outlines the early unsanitary conditions in Auckland town in the 1850's to 1870's and describes the various proposals to alleviate the problems. Depression delayed improvement and not until 1908 was the Orakei Scheme embarked upon. Discharge was to the Waitemata Harbour at Okahu Bay. The scheme was commissioned in 1914*

With increasing city expansion, the waters around the Orakei outfall became polluted and considered a menace to public health. In 1929 the Auckland and Suburban Drainage Board's newly appointed Chief Engineer, H.H. Watkins, recommended abandoning the Orakei outfall and replacing it with treatment works on Browns Island, some 2.5km offshore. The works would be connected to the reticulation system by a submarine sewer.

Controversy raged for several years and politics took over, the Browns Island Scheme eventually being overturned, even though construction had commenced. An overseas panel of experts appointed by the Board recommended the Manukau Scheme with treatment in large oxidation ponds and discharge to the Manukau Harbour in Mangere. This was adopted and commissioned in 1960

The paper describes the odour and midge difficulties which soon arose. The plant had had two major upgrades since then, fixed growth reactors (FGR) replacing trickling filters in 1981, and removal of the oxidation ponds and replacement of the FGR's with activated sludge reactors as part of the 2003 Project Manukau.

Keywords: *Orakei Scheme, public health, protests, engineering personalities, Browns Island, Manukau Scheme*

1. EARLY UNSANITARY CONDITIONS

Prior to any attempts by its early settlers to put in place a proper sewerage scheme, the central area of Auckland was drained naturally by the Ligar Canal which ran down Queen Street to the Waitemata Harbour. Because of poor oversight of 'nightsoil' collection and the ready disposal of horse droppings, the condition of the canal was deplorable. Work on constructing a sewer up lower Queen Street, while commenced in 1854, proceeded very slowly. A piped water supply from the Domain Springs exacerbated these conditions. As late as 1870 it was described by the NZ Herald as "That abomination, the Ligar Canal, is still a pestiferous ditch, the receptacle of every imaginable filth, bubbling in the noonday sun".

The Ligar Canal was finally covered completely in 1873, and the sewer, understood to be a brick structure ovoid in shape and of some two metres height, extended further up Queen Street. Interestingly, an upgrade of the Queen Street landscape in 2008 commemorates the Ligar Canal by a footpath-level trail of solar powered lights supposedly following its course.

General sanitary conditions, aptly described by Bush[1], were still deplorable and in 1878 under pressure from the public, Auckland City Council requested the advice of a visiting British hydraulics engineer, William Clark, who recommended a temporary scheme comprising an intercepting sewer which would terminate at Stanley Street, from whence chemically treated effluent would be pumped to discharge into adjacent St Georges Bay. In particular, the interceptors would eliminate the by-then notorious Wharf Outfall at the foot of Queen Street. Notwithstanding the relative economy of the scheme, city councillors did not act. By 1885 the country was enveloped by depression, killing off the desire to proceed with any scheme, even if of moderate cost.

The return of better times and mounting intolerance with the system of night-soil collection saw the commissioning in 1903 of Wellington civil engineer, R.L. Mestayer, who recommended the separation of stormwater and sewage, with sewage being piped up harbour to a septic tank at Cox's Creek. Again cost dismayed Council and a second opinion was sought of English engineer, G. Midgley Taylor, who scorned the proposal as extravagant. He recommended discharge on the out-going tide of screened sewage, off Takapurawha Point at Okahu Bay at the harbour entrance. Council was confused by the conflicting advice and awaited the appointment in 1906 of the new City Engineer, Walter E. Bush.

2. ORAKEI SCHEME

Bush threw his support behind the Okahu Bay scheme. In 1908 Midgley Taylor was recalled to implement the scheme, and the Auckland and Suburban Drainage Board created to oversee the entire Orakei project. Construction then progressed well and the main outfall works were opened in March 1914 with appropriate ceremony.

Some of the detailed features of the scheme are interesting both technically and historically. Quite large diameter or sized sewers were built because of the enormous volumes of stormwater as well as sanitary wastes the sewers were required to convey to the outfall works.

The main intercepting sewer runs 13,500 metres at a grade of 1 in 3000 from Avondale in the west to Orakei. It is of ovoid, or egg-shape, cross section, gradually increasing from 1.05m height by 0.7m, to 2.6m by 1.75m. To carry the sewage from those areas not able to be drained by gravity into the main sewer, four pumping station were constructed as part of the scheme.

Figure 1. *Main intercepting sewer to Orakei crossing Okahu Bay foreshore - Special Collection, Auckland City Libraries (NZ) 4.4429*

The Orakei outfall comprised twin 1200mm diameter cast iron pipes 380 metres long on cast iron cradles, discharging 7 metres below ordinary low tide. The storage tanks were divided into three longitudinal compartments of total capacity 37,000 cubic metres.

In anticipation of the Tamaki foreshore roadway, not constructed at that time, the reinforced concrete roofs to the storage tanks were built strong enough to carry tram traffic, the electric tram system, extending to the suburbs of Auckland, having been inaugurated in 1902. While tram traffic never eventuated, the tanks sustain heavy road traffic today.

Today, a portion of the storage tanks have been converted into Kelly Tarlton's Underwater World, where Auckland's citizens, most of them unknowingly, view sharks where their sewage wastes were once held for tidal discharge. The screenings building – described by Bush[2] as a handsome brick building on a stone base - housed a detritus removal plant, of bucket dredge type, three sets of 100mm screens followed by mechanically cleaned 15mm screens, and a screenings incinerator with its conspicuous chimney. Many are the false teeth sets recovered (and sometimes claimed from those on display). In the earlier, quieter, less technological times an operator wended his way by bicycle the length of the holding tanks to the valve house (now part of a popular café) to manually open the outfall penstocks on each outgoing tide. The screenings building itself (sans chimney) is today the fashionable Hammerheads Seafood Restaurant.

When the Orakei Scheme opened, the population served was 88,693 of a total population of some 100,000. It was capable of extension to serve 300,000.

3. BROWNS ISLAND SCHEME.

With increasing city expansion, sewerage reticulation kept pace and, by 1920, it was apparent that the waters around the Orakei outfall and adjacent shores were polluted and the discharge of effluent there a menace to health. Also, the expanding reticulation saw an increasing number of sewage outfalls into both the Waitemata and Manukau harbours. The Drainage Board's Engineer-Secretary Mr. H.H. Watkins was sent overseas in 1929 to study the various methods of sewage disposal then available. He investigated a large number of sewerage schemes and noted that the dilution method, untreated discharge into a large body of water, was the choice most commonly preferred and also the most economical system available.

Watkins' report of December 1931 proposed to abandon the Orakei outfall and replace it with treatment works on Browns Island, some 2.5km offshore, with discharge of screened and settled sewage to an outfall in the adjacent Motukorea Channel. The works would be connected to the reticulation system by a submarine sewer.

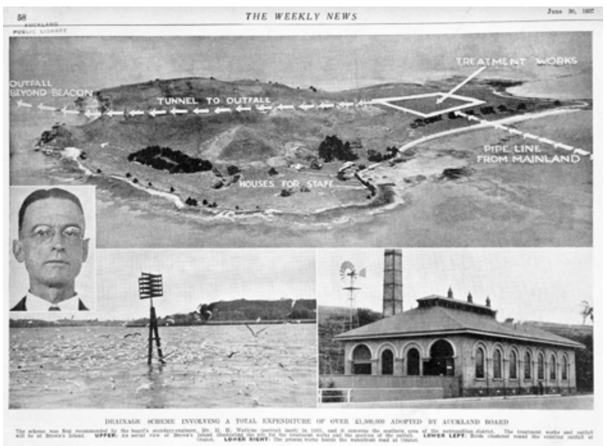

Figure 2. *Proposed Browns Island Scheme (top) and existing Orakei screenings building and outfall. Insert photo of HH Watkins Auckland Weekly News*

There was, however, some opposition; principally from those parties who could see themselves likely to be affected by the discharge. Amongst these were the Tamaki Ratepayers and Residents Association, and the Tamaki Yacht Club, which postulated that conditions would be little better than the existing Orakei outfall. However, public dissatisfaction with the existing system, which by now was serving 158,000 and under considerable strain, muted these objections.

E.F. Borrie, Drainage Engineer to the Melbourne and Metropolitan Board of Works (aged 41) and G.A. Hart, who was about to retire as Wellington City Engineer, were commissioned to review the proposal and reported in February 1936. They endorsed the Browns Island scheme; but subject to float tests to confirm the anticipated movement of the effluent field. By May 1937 the completed float tests, independently checked, were reported on, confirming the efficacy of the proposed Browns Island outfall and dismissing the need for disinfection of the discharge, although it did recommend chlorination be available for use during prolonged periods of dry weather.

The delay caused by the review was costly as, .with the Depression receding, the government subsidy on labour costs was withdrawn, checking the Board's enthusiasm. Then the outbreak of World War II put all such projects on hold.

In 1943, with a successful conclusion to the war in sight, interest in the scheme revived. The Auckland & Suburban Drainage Board was dissolved and the Auckland Metropolitan Drainage Board was formed. The Board put forward a Bill for a metropolitan drainage authority, which was passed in 1944, notwithstanding a petition which branded the Browns Island proposal 'a serious blunder and permanent disfigurement of the most beautiful harbour in the Pacific'.

4. CONTROVERSY OVER SCHEME

Although opposition seemingly waned, behind the scenes, however, trouble still stirred, stoking a controversy, ably chronically by Bush[3], that was to last another twelve years.

In addition to the directly affected critical organisations there was another dissenting party, the Drainage League, small and ineffectual initially; but to its ranks it attracted one Dove-Myer Robinson.

Robinson was a businessman, until that time little interested in civic affairs; but destined, through his initial interest in the sewerage controversy, to become the longest serving mayor in Auckland's history.

Having attended one of the initial meetings of the Auckland and Suburban Drainage League (to give it its full name), he quickly became the League's central and dynamic figure. The League's goal was to prevent the Browns Island scheme coming to fruition and continued discharge of wastes into the recreational waters of the Waitemata Harbour.

Robinson worked on the public's prejudices to "swimming in their own excreta'; he became conversant in sewage treatment methodology, and developed an allied interest in waste composting.

The League criticised the Browns Island proposal, formulated as far ago as 1931 and now 14 years old, as being obsolete, and stressing its similarity to the discredited Orakei Scheme. They hammered for alternatives to be considered

The League's overriding fear was that planning for the Browns Island scheme would proceed beyond the point of no return. However the inconvenient location of the proposed treatment plant on an island and the Board's lack of skilled staff made progress slow. Watkins retired in September 1947, creating further hiatus.

Re-elected League president in 1947, Robinson expounded the idea of all sewage being directed to Westfield where sludge would be retrieved from sedimentation tanks and the effluent held in an artificial lake formed by building a low retaining dam beneath the Mangere Bridge. Profits would accrue from harvesting water hyacinths and mixing these with the settled sludge to form compost for sale.

In October 1947 the first case of a new epidemic of poliomyelitis (infantile paralysis) was noted. It was thought, but not conclusively proved, that bathing in polluted seawaters was the cause and bathing was prohibited at all inner-harbour beaches. By the end of November the first death had occurred. All Auckland schools closed and, by the time they reopened a month later than usual in March 1948, 113 positive cases had been hospitalised and there had been eight deaths.

5. ENGINEERING CONCERNS RE SCHEME

James P. Porter BSc MICE, aged 51, whose earlier upbringing had been in New Zealand and whose recent work experience was with the London County Council, which gave him familiarity with discharge of sewage to tidal waters, was appointed Chief Engineer on 6 June 1948. Porter found that little had been accomplished since the retirement of Watkins nine months earlier and no doubt was dismayed at the lack of experienced technical staff available

Porter quickly set about reviewing the Browns Island scheme. His end of July report identified that, with the intervening population growth since the scheme's inception, it would serve Auckland's needs only if the Westfield industries treated their own wastes. Otherwise, the Browns Island scheme could serve only immediately contiguous residential areas plus these industries, and other satellite schemes would necessarily be required.

Porter then unveiled a modified Dual Scheme in January 1949, which retained the Browns Island proposal for the urban area tributary to the Waitemata, with a separate plant to serve the Manukau industries and the southern area.

The Auckland Harbour Board agreed discharge standards and the Department of Health approved these as 100B.coli/100ml beyond “a half-mile of the shores” of the island, with such standards to apply other than on the ebb tide.

As to the Browns Island proposal itself, while supportive of it, he was concerned at the lack of test borings and geological investigation of the submarine sewer route to the island. Submarine borings on the alignment of the Browns Island sewer were carried out in early 1949.

Porter still had concerns regarding the feasibility of the submarine sewer, particularly as the borings had identified an infilled valley on the sewer alignment. The advice of Sir William Halcrow, renowned British engineer, who had been retained to act on Auckland’s underground railway, was sought. He advocated a tunnel under the seabed with a light railway for construction of the sewer.

As to new staff, Ronald Hicks, a chemist, was appointed in May 1949 in recognition of the seriousness of the industrial waste problem. Aged 43, Hicks had been manager of sewage purification works at Hamilton, Scotland. As will be seen, he was to prove a ‘hick-up’.

The period 1949-1951 was consumed by political activity involving a commission of Inquiry into the Board’s scheme. The drainage commission completely endorsed Porter’s Dual Scheme and trampled on the League’s ambitions for ponds and recovery of nutrients by water hyacinths – indeed, going further, and condemning oxidation ponds

By this time the need for a scheme was desperate, Orakei being only one of over two dozen outfalls discharging raw wastes into the Waitemata and Manukau harbours, fourteen of these serving industries around the Westfield - Penrose area including the freezing works, which alone were equivalent to a population of 300,000 persons.

However, the Board was not over all its hurdles yet. Hicks had broken ranks, publicly disagreeing with the Board’s scheme at the Local Bills Committee hearing in October 1951, saying that the scheme’s bacteriological standards would fall distinctly short of what was acceptable. Porter was livid – and pointed out that the effluent was to be discharged only on the outgoing tide and standards applied only to incoming tide.

Hicks was silenced. But there was additional criticism from some prominent local engineers - Ralph Worley, about to become the newly formed North Shore Drainage Board’s first consultant, and Hugh Vickerman DSO OBE, ex Deputy Chief Engineer of the Public Works Department and a past President of the NZ Institution of Engineers, both expressing grave doubt regarding the feasibility of construction of the submarine sewer.

6. DRAINAGE LEAGUE SCHEME

The Drainage League was awakened and Robbie, as Robinson began to be popularly known, saw his chance, early in 1952, when a casual vacancy in the council occurred. He ran, his win ordaining that he be appointed to the Drainage Board.

Robbie then turned to advocating the League’s alternative scheme - providing for all sewage to be treated by oxidation ponds located between Puketutu Island and the Mangere foreshore in the Manukau Harbour

Robbie aggressively deprecated Porter’s expertise, both at the Board table and in public. Matters came to a head when the City Council, in anticipation of the Browns Island scheme being implemented, proposed to utilise a planned trunk sewer serving the Glendowie area as a temporary septic tank with discharge at the Karaka Bay foreshore until such time as it could be connected to the submarine sewer to the island. The announcement that swimming at Karaka Bay would be prohibited galvanised a large public meeting protesting the proposal. Board engineering officers Mynott and Rowntree had to bear the brunt of uncivil criticism expressed at the meeting.

Then doubt again arose regarding the submarine sewer, Sir William Halcrow’s major report to the Board in September saying the proposal was probably reasonable as long as the probability of earth tremors was low. The Board’s staff began to lose confidence, particularly when tenders for initial works greatly exceeded estimates.

Following considerable turmoil at Board level, in March 1953 the Board reviewed competing schemes in a debate which extended over two days. The meeting reaffirmed the Browns Island scheme and awarded to Etude et Enterprises Ltd, which had been invited to re-tender following unacceptable earlier tenders, a contract for construction of access works, the submarine sewer and the Browns Island outfall in the sum of £1,914,332.

In order to achieve such progress, the Board had taken on additional engineering staff. Charles C. Collom BSc (Eng) MICE, later to become Chief Engineer, took up his appointment as Senior Civil Engineer in November 1951. Along with the appointment of a number of young graduate engineers then and in early 1952, including the writer, this gave rise to a buoyant morale in the engineering office.

Robinson continued his criticism of the scheme and particularly of Porter, going so far as to move the Board request a public investigation into the affairs of the Board over the period of Porter's tenure. Even at the ceremony marking the commencement of construction, he expressed an aside to Collom 'that the scheme could still be stopped'.[3]

At the 1953 local body elections several League candidates including Robbie, were appointed to the Board and at its first meeting in February 1954 Robbie was elected chairman.

7. OVERSEAS PANEL OF EXPERTS

Immediately Robertson lead the board into an intensive review of all aspects of the then adopted seven-fold scheme including the submarine tunnel, since abandoned in favour of a seabed trench. Most board members appreciated that proper technical consideration was beyond their competence and, in the face of wavering confidence by staff, opted to slow down the Browns Island scheme and seek review by an overseas panel of experts.

Figure 3. *Board in session – Robbie at helm. Mynott, Rowntree and Hicks at rear table*

From a short list of 21 nominations prepared by staff, the March meeting of the Board selected a panel of four engineers, three from the west coast of the United States, two of which had previously worked together, one from England and one chemist from Britain. There was considerable allegation of bias regarding selection as the US engineers had a heavily weighted background in development of oxidation ponds, Dr David H. Caldwell's firm Brown & Caldwell having designed sewage treatment plants based on this process for several Californian communities. Also, he had had a past close working association with the most senior member of the panel, Emeritus Professor Charles G. Hyde, who became the informal chairman of the panel.

The selection of A.M. Rawn, Chief Engineer and General Manager of Los Angeles County Sanitation District and an internationally renowned expert in tunnelling for ocean outfalls, was free of criticism, as was the choice of John T. Calvert, senior partner John Taylor & Sons, London. The fifth member of the panel was English chemist and former sewage works manager Dr Harold Wilson.

Notwithstanding the shadow over selection, the panel worked very fast delivering within a month of arrival on the 18 April an interim opinion on the proposed scheme to the effect that it could not comply with the official discharge standards set by the approving authorities.

Calvert, in a minority report, advocated a reduction in standards, even though those adopted were now to apply at bathing beaches rather than adjacent to the outfall, and supported the Browns Island Scheme, as against others, on the grounds of cost, ability to proceed immediately and on the principle he favoured of dealing with wastes of an area within its own watershed. He also expressed concern regarding risk of smells from oxidation ponds of the size proposed in the alternative League scheme. As to reduced standards, all except Calvert said it would require further testing which would take up to a year. Calvert said there was a reasonable chance but the only way to be certain is to put the scheme into operation and find out.

Porter's position had become untenable. He had been humiliated by the Board and its antagonistic chairman. At the March meeting he was stripped of his role as Chief Executive Officer and Hicks was vested with the right to report directly on sewage purification and treatment. At its meeting on 19 May 1954 Porter tendered his resignation. At the same meeting the Board resolved not to proceed with its Browns Island scheme.

8. MANUKAU SCHEME

Meanwhile the panel laboured industriously and by 1 July had completed its report[4]. On 7 July the Board adopted the panel's recommendation for the Manukau Scheme on lines very close to the conception of the Drainage League; viz. all sewage was to be treated in a plant on the shores of the Manukau and in four oxidation ponds lying between Puketutu Island and the mainland near Ihumatao.

A high quality effluent was expected, treatment comprising pre-aeration and grit removal, primary sedimentation, oxidation by trickling filters as required and recirculation through the extensive oxidation ponds, some 550 hectares in area, before discharge to the harbour on the outgoing tide. Sludge from the sedimentation tanks would be digested and captured methane gas used to generate electricity in dual-fuel engines, excess generation being fed to the national grid.

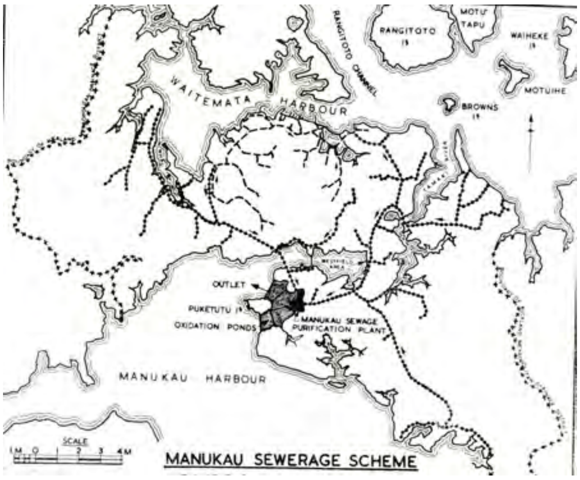

Figure 4. *Scheme as Adopted - AMDB*

Brown and Caldwell, Consulting Civil and Sanitary Engineers of San Francisco were appointed consultants for the treatment plant and pumping stations

Design work on the Manukau Scheme commenced in November 1955. The first contract, for the Hillsborough section of the main western interceptor, was awarded to Etude et Enterprises in compensation for the abandoned Browns Island works. The tunnel itself was the largest single local body project undertaken to that time, being 3.2km in length at an average depth of 50m and large enough to accommodate a narrow-gauge railway with a battery operated loco to haul the wagons of spoil loaded by the EMCO B12 rocker shovel at the tunnel heading. The tunnel face was broken down by manual drilling and explosives. The tunnel was backfilled after the laying of the 1350mm diameter concrete sewer pipe.

The Manukau Wastewater Treatment Plant itself was switched on at dawn on 24 September 1960 by the Board Chairman the Honourable Thos. Bloodworth, the writer, now having progressed to the position of Design Engineer (Special Works), indicating which button he should push to start the pumps at the Orakei Pumping Station thus diverting the flow to Mangere.

9. MANUKAU SCHEME PROBLEMS

Problems soon arose – the smells that Calvert thought could arise from such large ponds had hardly begun to annoy local residents when the midge *chironomus zealandicus* arrived *en masse*. The fact residents were assured, and indeed knew, that midges predated the construction of the plant did nothing to improve their Christmas of 1960.

A 700 strong meeting of Mangere residents threatened to withhold the area's levy to the Board. Caldwell returned in March 1961 at the Board's request (and Robbie's personal expense).

He addressed a public meeting of some 500, assuring it that he retained confidence in the pond system once it settled down and that the provision of sludge lagoons would alleviate odours from temporarily mal-functioning sludge digesters. He departed – as did the summer conditions conducive to midge breeding.

Figure 5. *John Fitzmaurice, Design Engineer (Special Works); Vince Taylor, Plant Engineer; Dr Dave Caldwell and Ron Hicks, Chief Chemist & Plant Superintendent. 18 April 1961. NZ Herald photo*

Summer of 1961-62 was very trying for the Board, with calls for a Ministry of Health Inquiry from the Manukau County Council.

The third summer 1962-63 saw the problem lessen at Mangere, but midges struck in such swarms at the 43 hectare ponds of the North Shore Drainage Board's new plant at Rosedale Road that there were serious proposals to dispense with the ponds. Dr Donald Spiller, an entomologist with DSIR was employed to study the midge problem at Mangere. With the dredging of the ponds to a minimum depth of one metre, at which depth there is insufficient light to foster midge emergence, and with increase in biochemical loading to the ponds, both midge and smells abated.

There were dramatic improvements in the water quality of both the Waitemata and Manukau harbours, even with loadings to the plant that greatly exceeded expectations.

The legacy of the Drainage League is that both the Auckland and North Shore systems are based on oxidation ponds, as is the Bromley works in Christchurch and that many other community treatment systems are like based. In fact, as of 1986, ninety-eight communities in New Zealand with populations greater than 1000 were being served by oxidation ponds[5].

Another gift to Auckland as a consequence of the drainage controversy was Robinson's six-term tenure as mayor, a total of eighteen years' service to the city.

Notable among contractors involved with the scheme other than Etude et Enterprises, were Wilkins & Davies Construction Co Ltd and mechanical sub-contractors Mason Bros Ltd on construction of the plant proper; New Zealand Earthmovers Ltd on oxidation pond embankment construction; and Green & McCahill Ltd on trunk sewer construction.

The overall scheme is described by Collom[6], who revisited the plant operational problems in 1964[7]. By this time the number of pumping stations in the scheme, described by the author of this paper[8], had increased from the original four to 36, twenty-three being in operation or under construction.

C. C. Blow Secretary — *C.C. Collom Chief Engineer* — *J.Allen Treasurer*
H. S. Bunby — *W.L. Mynott*
R. J.Franklin — *R. Hicks*
W. V. Clay — *D. Spiller (DSIR)*
M. R. Sargent — *J. R. Fitzmaurice*
J. R. P. Lee — *E. H. M. Adams*
L. G. Smith — *Absent JB Rowntree* — *K. Burke*
R. Gilmour — *R. M. Duckworth*

Figure 6. *Chief and Principal Officers of Drainage Board, 1963 Sparrow Photo*

The plant operated satisfactorily over the next twenty years; although with close attention having to be given to both pond loading and midge control. These ponds were the largest in the world in full-time service, only some industrial ponds treating seasonal agricultural wastes being larger

10. PLANT 1974 UPGRADE

Progressive increased loading to the plant necessitated a major increase in the land-based facilities. In 1974 the Board commissioned a report by Caldwell Connell (an Australian affiliate of Brown and Caldwell) which recommended replacement of the rock-filled trickling filters with nine large high-capacity plastic media Fixed Growth Reactors.

A nation-wide depression in the mid-seventies deterred expenditure and also slowed down industrial growth so that, in the event, only four reactors were built.

The Fixed Growth Reactors were cylindrical concrete structures, about the same diameter (53.3m) as the trickling filters but about five times their height. Each contained about 34 million small plastic media units. These polypropylene spoked rings, 97mm diameter by 51mm depth, were random packed into each reactor. Provision was made for both natural and, if needed, forced ventilation of the reactors. With such aeration, primary effluent applied to the reactors would be purged of dissolved and colloidal impurities by the zoogeal growth which would build up on the media.

Overall design of the upgrade was undertaken by Caldwell Connell and local consultants Beca Carter Hollings and Ferner. The main contractors were Bitumix Ltd and McMillan and Lockwood. The latter firm was familiar with such undertakings having built the both the Palmerston North Sewage Treatment Plant designed by Brown and Caldwell and D.L. Steven of Christchurch, and the Hamilton Pollution Control plant designed by Steven & Fitzmaurice. McMillan and Lockwood even persuaded the Auckland Regional Authority, now the owner of the plant, to accept an alternative design for the reactors, utilising a free-standing post-tensioned prestressed cylinder on a sliding base in lieu of wall panels fixed to the base slab. Construction was complete by 1981 at a cost of $92.5M.[9]

A minor but interesting controversy arose regarding the media used in the Fixed Growth Reactors. The supply contract was awarded to AHI Chemical Engineering Services for Filterpak media as marketed in the USA by Mass Transfer Inc. Because of the volume required, alone valued at $5.4M, AHI set up a local manufacturing plant. Strict import control was in vogue at this time and when similar Fixed Growth Reactors were proposed for extensions to the Bromley Plant in Christchurch. AHI opposed the importation of Flocor, a modular crate-type plastic media favoured by the writer's practice, which had the design commission, because of its more open structure with a lesser propensity to blockage. Only strenuous appeal at government ministerial level won approval to import the media which was shipped in flat sheets and assembled into its crate form locally.

Gradual and progressive settlement and compaction of the random media in the Auckland reactors caused poor drainage and ponding of the applied primary effluent. Also unforeseen was the undesired efficiency of the tower-like structures to strip out odours which were inherent in the trade wastes which flowed into the plant from industrial sources as diverse as meat wastes to fertiliser manufacture. These odours were serious enough to require later covering of the FGR units. The direction of the forced ventilation was then reversed and extracted air passed through the original rock trickling filters for odour removal

The Christchurch plant at Bromley experienced similar odour troubles, although without effluent ponding, and had to resort to a similar response.

Figure 7. *Manukau Sewage Purification Works after covering of Fixed Growth Reactors – ARA Photo*

Auckland's growth continued, as did the wastewater load to the treatment plant, and a wide-ranging study[10] of future needs for additional treatment and disposal options was undertaken by the Auckland Regional Authority (ARA), which had taken over metropolitan drainage responsibilities in 1964. By 1987 the plant was treating a tributary population of 630,000, with an industrial and commercial load equivalent to an additional 700,000

11. PROJECT MANUKAU

Consequent to local government reorganisation in 1989 the plant has, since 1992, been owned and operated by Watercare Services Ltd., a local council organisation, and renamed the Mangere Wastewater Treatment Plant. Watercare recognised that a major plant upgrade was going to be necessary as a consequence to poor pond performance and potential future loading to the plant. It embarked on an extensive public consultation programme in planning the upgrade of the treatment plant. It took the approach that it would implement the most desired outcome the consultative process identified.

Wastewater 2000, as the consultative process was styled, culminated in Project Manukau as described below.

Figure 8. *Mangere Wastewater Treatment Plant prior oxidation ponds decommissioning – Watercare photo*

Project Manukau has seen the progressive removal of the oxidation ponds and their treatment capacity replaced by nine large BNR (biological nitrogen removal) activated-sludge reactor-clarifiers.

Each 'doughnut' shaped reactor-clarifiers comprises an inner 52m diameter circular clarifier surrounded by peripheral aerobic and anaerobic activated sludge compartments. Overall diameter is 78m and water depth 7.7m. Each sits on a concrete base of 1100m3, formed in one pour.

Figure 9. *Reactor-Clarifiers –Watercare photo*

Other process changes and upgrades to effluent quality include pre-primary influent milli-screening, effluent filtration and ultraviolet disinfection. The effluent is held in a storage basin for discharge on the outgoing tide. Improved capture and treatment of solids includes primary-sludge gravity thickening, centrifuge sludge-dewatering, and lime stabilisation. Sludge lysis (ultra-sonic vibration to release moisture) was also added for a time; but its use has been discontinued, as it was found to be ineffective.

Some residual midge problems remain with the open effluent channel and the effluent storage basin; but the upgrade has considerably reduced both midge and odour complaints. There has been a marked improvement in harbour water quality, particularly in bacteriological terms and the foreshore area previously used by the ponds has been returned to recreational use.

Figure 10. *Mangere Wastewater Treatment Plant after Project Manukau upgrade – Watercare photo*

The exposed nature of the effluent channel and, particularly, the effluent storage basin met the desire of Maori for "contact with the earth" before discharge. However, these shallow, slightly polluted, fresh water areas are ideal for midge-breeding, necessitating control by chemical spraying. To eliminate the on-going cost of midge control, Watercare intends direct discharge to permanent harbour waters, so removing the midge habitat.

The Project Manukau upgrade to the Mangere Wastewater Treatment Plant became fully operational in terms of its resource consents in October 2003 at a cost of $460M.[11]

It was a sign of the times that the community's environmental aspirations superseded concern over costs – a vastly different attitude to the frugality of the previous 150 years.

12. ACKNOWLEDGEMENTS

Acknowledgement is made to Auckland City Libraries for use of photographs and to Watercare Services Ltd for use of material and photographs provided.

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See over page for Auckland Sewerage Timeline

AUCKLAND SEWERAGE TIMELINE

1860's	Nightsoil collections inadequate. Queen Street main drain, the Liger Canal, called 'a pestiferous ditch'.
1873-	Liger canal finally covered in and Queen Street sewered.
1878-	British Engineer William Clark recommends an intercepting sewer eliminating Wharf Outfall at foot of Queen Street.
1903-	Auckland population 100,000. Eminent London engineer, Mr G Midgley Taylor submits plans for the Orakei Scheme.
1914-	Orakei Outfall opens. Reticulated sewage empties into the Waitemata Harbour at Okahu Bay.
1920-	As population increases, it becomes apparent that shores and waters at Orakei are polluted.
1928-	By this time there are a number of sewage outfalls into the Waitemata and Manukau harbours.
1931-	H. H. Watkins, Engineer-Secretary to Drainage Board, recommends that Browns Island be developed as a site for sewage treatment facility.
1944-	The Auckland Metropolitan Drainage Board plans to proceed with the Browns Island proposal, but is met with strong opposition.
1945-	Suburban Drainage League formed to oppose the Browns Island Scheme. Dove-Myer Robinson becomes its leader.
1947-	Poliomyelitis (infantile paralysis) outbreak, thought to be associated with contact with polluted bathing waters, provides incentive to hasten progress.
1953-	Drainage Board awards contract to construct access tunnel and submarine sewer for Browns Island Scheme.
1954-	Dove-Myer Robinson elected chairman of the Drainage Board. Board suspend work on Browns Island Scheme and appoints panel of overseas engineering experts to review scheme.
1955-	Manukau harbour is recommended as the best disposal option for a more comprehensive treatment facility for greater Auckland on a site at Mangere.
1956-	Design and construction of the Manukau Sewage Purification Works and interceptor sewer system commences.
1960-	Manukau Sewage Purification Works opens in September at estimated cost of £15M. Oxidation Ponds cover more than 500 hectares – then largest in the world.
1962-	Odour and midge nuisances become prevalent. Commission to Inquire into Alleged Nuisances in Auckland Metropolitan Drainage District sits.
1970-	While environmental quality of the upper Manukau mudflats improves considerably; periodic odour nuisances from the plant continue.
1974-	Pond system is reaching its treatment capacity, and planning commences for increasing plant treatment capacity.
1981-	Treatment capacity increased by commissioning new Fixed Growth Reactors at cost of $92.5M.
1987-	Growth continues. Connected population now 630,000 with additional commercial and industrial equivalent population of 700,000.
1992-	Watercare Services Limited takes ownership of the re-named Mangere Wastewater Treatment Plant. Initiates 'Wastewater 2000' public consultation.
1998-	Project Manukau, a $460 million upgrade, including return of oxidation ponds to the sea and incorporating activated sludge, gets underway.
2003-	The upgraded Mangere Wastewater Treatment Plant was officially opened in April 2003.

3rd Australasian Engineering Heritage Conference 2009

American bridges in New South Wales 1870-1932.

Don Fraser PhD, FIEAust (ret), Engineering Heritage Committee, Sydney

SUMMARY: *New South Wales Government Railways and the Department of Public Works began with British technology, particularly for rail and road bridges such as the expensive iron lattice girders. Long-serving Engineers-in-Chief, John Whitton and W C Bennett, applied their authority to exclude contemporary American bridge technology. However, by 1890 the merits of American bridges were well known and had economic appeal for Government funding. The effect was that in 1894 there was an abrupt and complete change to American Pratt truss bridges, which became the standard for the next fifty years. The first uniform application to railways was for the new standard gauge North Coast Railway, 1911-1932. They are now an historic class of bridges of high heritage significance. For road bridges, American Howe timber trusses were dominant post-1894 and 29 are on the State Heritage Register. Also, steel Pratt truss road bridges from this period are still in-service. This paper details the change to American bridge technology.*

1. INTRODUCTION

By the end of the Whitton era the three trunk lines of the New South Wales (NSW) railways, **N**orth, **W**est and **S**outh**,** Figure 1, had set the pattern of the network for branch lines spreading out into the western wheat belt and grazing country. Two missing regions were the North Coast and Far South Coast because they were well served by coastal shipping. The wealthy, politically influential Country Lobby dominated the approvals and budgets of railway projects.

Figure 1. *NSW railway network 1885-1895 [visual overview only]*

As befitting a British colony, railway technology was mostly British, particularly the bridges. But American locomotives and rolling stock were giving good service, so why not American bridges?

John Whitton, Engineer-in-Chief (1856-1890), despite being eulogised as the "father of NSW railways", was ill-disposed to American bridges. Consequently, three types of British railway bridges Figure 2, monopolised the bridge population, the wrought iron lattice structure, and ballast-topped timber Queen-post trusses (QPT) (ex Brunel) and ballast-topped timber openings (BTTOs), (Fraser 1995).

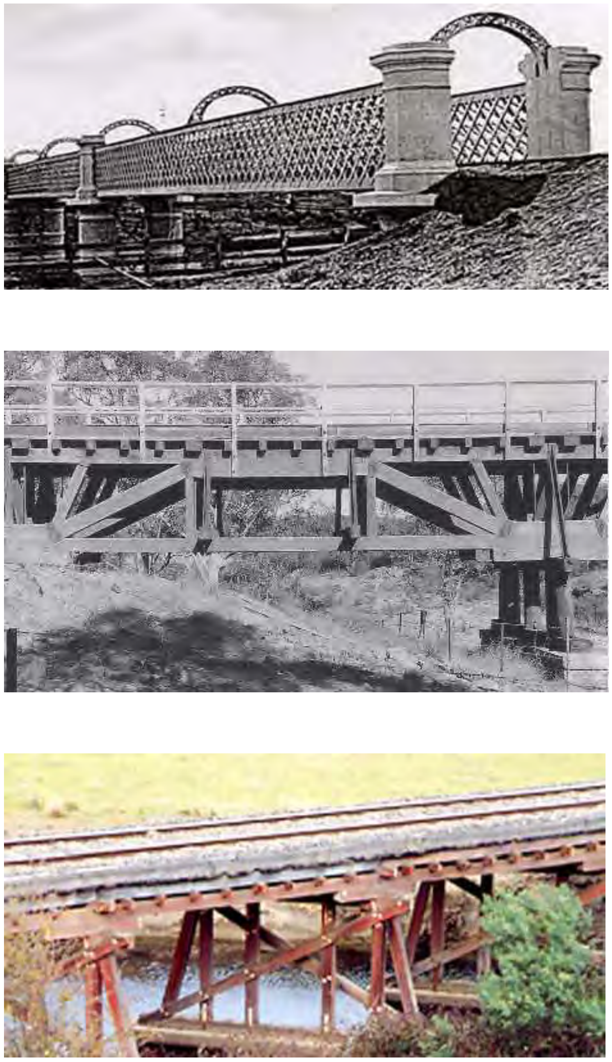


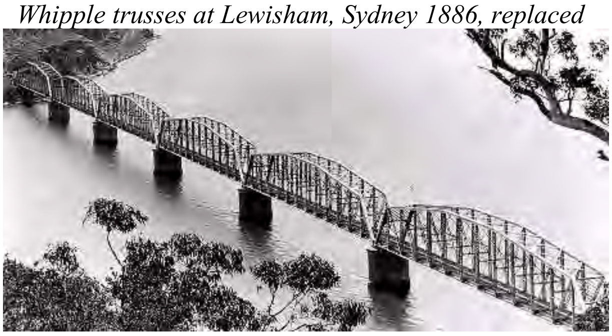
Figure 2. *British railway bridges, 1876 wrought iron lattice bridge at Bathurst, 1886, a Queen-post truss near Tenterfield and an 1886 BTTO near Tarago*

All types had their merits. The lattice bridges were expensive but they were effective for crossing major rivers, were sturdy and long serving, ten survive with seven still in service. The QPTs and BTTOs were built from strong durable ironbark and carried a ballasted track which could be fettled as for the adjoining normal trackwork. Unfortunately, the timber deck supporting the ballast was subject to wet-rot which led to difficult and expensive deck replacements.

Extant Brooklyn Bridge, largest in the world in 1883

Extant Whipple trusses, Shoalhaven River, Nowra 1881

Whipple trusses at Lewisham, Sydney 1886, replaced



First Hawkesbury River railway bridge 1889, replaced

Figure 3. *Brooklyn Bridge and American style railway bridges in New South Wales.*

But the Americans had already demonstrated their technical proficiency with the 1883 Brooklyn Bridge, Figure 3, and many long-span railway bridges. So, at the same time three American metal trusses were constructed in N S W outside Whitton's authority without causing a change from British lattice bridges.

The first element of change came in 1883 with the appointment of Sydney University's first Professor of Engineering, William Henry Warren, who although being a British academic, had an international attitude to engineering. His lectures included all the latest knowledge of American bridge technology. Three famous bridge engineers were among his early graduates; Harvey Dare who designed the durable composite timber truss that now bears his name; J J C Bradfield of Sydney Harbour Bridge fame; and J W Roberts who designed the steel bridges for the North Coast Railway and the double-deck bascule bridge over the Clarence River at Grafton.

Then in 1888 there was a major re-organization of the NSW railway system whereby new constructions remained with the Department of Public Works (PWD) and the existing network became the New South Wales Government Railways (NSWGR) under a new Commissioner, E M G Eddy. He immediately implemented an austerity programme to rein in the extravagance of the 1880s boom-time.

In 1894, at the height of a financial Depression, there was an immediate change to American steel Pratt truss bridges, Figure 4. They were structurally and economically more efficient, much quicker to erect and easier to maintain – no more expensive lattice bridges, rail or road.

Figure 4. *An American steel Pratt truss*

The first use of American steel trusses occurred on the Far North Coast where an isolated section of railway from Lismore to Murwillumbah, see Figure 1, was opened in 1894 to serve a proposed port at Byron Bay and link with a Queensland narrow gauge railway from Coolangatta to Brisbane.

However, after Federation in 1901, the prospect of another break of gauge between capital cities doomed the isolated line to become only a branch line of the future standard gauge North Coast Railway, Sydney to South Brisbane in 1932.

And so the die was cast favouring American bridges, such that in 1894 the new Chief Engineer of the

Railway Construction Branch, Henry Deane, visited the USA to inspect railway practices in the hinterland, and found much that was suited to building Pioneer Lines in Western NSW (Deane 1900). Of particular note was the American use of timber girder bridges without decks, simply rails on cross-timbers called transoms, hence the acronym TTTO for transom-topped timber openings, Figure 5. Forming a structural skeleton, their initial construction costs and long-term maintenance were much cheaper than Whitton's BTTOs. Thousands of TTTOs exist on the NSW branch lines plus some American timber Howe truss bridges, Figure 6.

Figure 5. *Constructing a railway TTTO 1913*

Figure 6. *A timber Howe truss railway bridge 1909*

The Howe and Pratt trusses were two of the many patented timber bridges in America during the 1840s and named after their respective originators William Howe and the Pratt brothers. The distinguishing feature between the two trusses is in the arrangement of the sloping and vertical web members, and the forces in them. Howe truss diagonals are in compression, well suited to stocky timber members, with the vertical iron rods in tension. Longer diagonals are better in tension, hence the opposite slope to the Howe truss, with the shorter verticals in compression. This becomes the Pratt truss, see the basics illustrated in the **APPENDIX**.

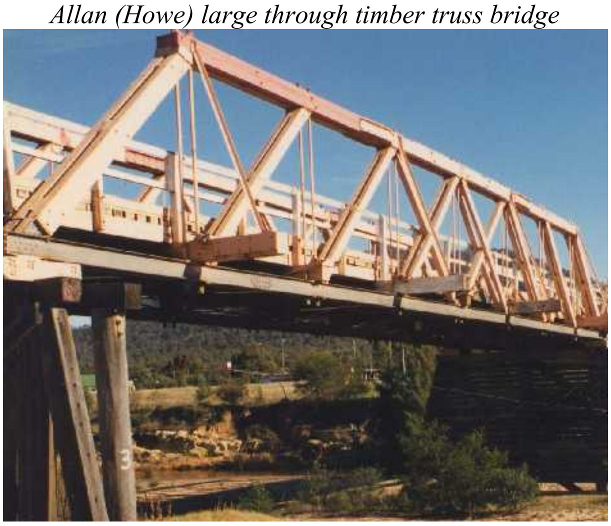
2. TRUSS ROAD BRIDGES

The first American type metal truss road bridge was built as early as 1870 over the Macquarie River at Bathurst, Figure 7, whereas 27 lattice bridges were built thereafter up until 1894. By then, three Public Works

1870 Pratt truss bridge over Macquarie River, Bathurst

Allan (Howe) normal half-through timber truss bridge

Allan (Howe) large through timber truss bridge



Dare (Howe) composite truss bridge
[Fig.7 continues]

De Burgh (Pratt) composite truss bridge

Figure 7. *American truss road bridges, NSW*

Roads and Bridges Branch bridge engineers, Percy Allan, Harvey Dare and E M de Burgh, began adapting the two American trusses for road bridges,, Figure 7. Named after each of them, they were immediately successful and many are still in use in NSW (Fraser 1985).

Despite the priority given to railways for steel Pratt trusses, there were a few built for roads, particularly for major crossings over large flood-prone rivers, Figure 8.

Figure 8. *The 1905 steel Pratt trusses for the Luskintyre road bridge over the Hunter River near Lochinvar. Note the thin narrow strips for the tension diagonals.*

3. THE NORTH COAST RAILWAY

So, a uniform set of bridges, American steel trusses for spans exceeding 33 m, steel girders for intermediate spans of 20 m and TTTOs for small 8 m spans, was available for the next major railway project in NSW, the North Coast Railway.

Initially, three new sections of Pioneer Lines had been built on the Far North Coast, Casino to Lismore (1903), Grafton to Casino (1905) and Casino to Kyogle (1910). The first was to remain a branch line and the latter two were upgraded by late 1930 as part of the standard gauge railway to South Brisbane.

In the meantime, the State Government of NSW tabled a proposal for a North Coast Railway from West Maitland to South Grafton, Figure 9, but closing the gap to Grafton across the Clarence River was left to the future, after the new line could justify the estimated cost of £2 million (Gunn 1989).

In 1908, Newcastle welcomed the Government's initiative , seeing the line as not only opening up the North Coast country but adding to the importance of Newcastle and making it possible to build lines from the New England high country to the coast. Important coastal towns such as Taree, Wauchope/Port Macquarie, Kempsey and Coffs Harbour, indeed the whole of the coastal strip, would benefit in the change from the vagaries of the coastal shipping trade.

Figure 9. *Extent of the NSW railway network by 1925 including the North Coast Railway completed in 1923 [visual overview only]*

An added strategic factor came from the 1911 Royal Commission (Gunn 1989) where the Chief of the General Staff of the Australian Military Forces made a plea for uniform gauge railway connections between Queensland, Northern NSW and on to Victoria and South Australia, a plea not answered until 1930 to South Brisbane, 1962 to Melbourne and 1970 to Perth.

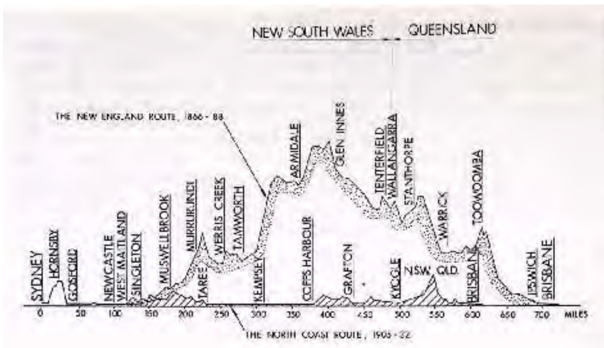


Figure 10. *Gradient profiles, steep Main North Railway, flatter North Coast Railway*

Another item of merit for the new coastal route was that it would be 160 km shorter than the 1888 Main North to Wallangarra (an even greater difference in the total distance to Brisbane) and overall it would have a much flatter gradient profile, Figure 10, which would result in a significantly greater operational efficiency.

4

4. NORTH COAST RAILWAY BRIDGES

An initial hesitation about the North Coast Railway was the frequency of wide navigable rivers such as the Manning, Hastings, Macleay, Nambucca and Bellinger, requiring long expensive bridges possibly with opening spans for the large river craft, particularly the ocean-going ships. However, a route was chosen that kept the bridges well upstream of the navigable sections where the small craft could pass under them.

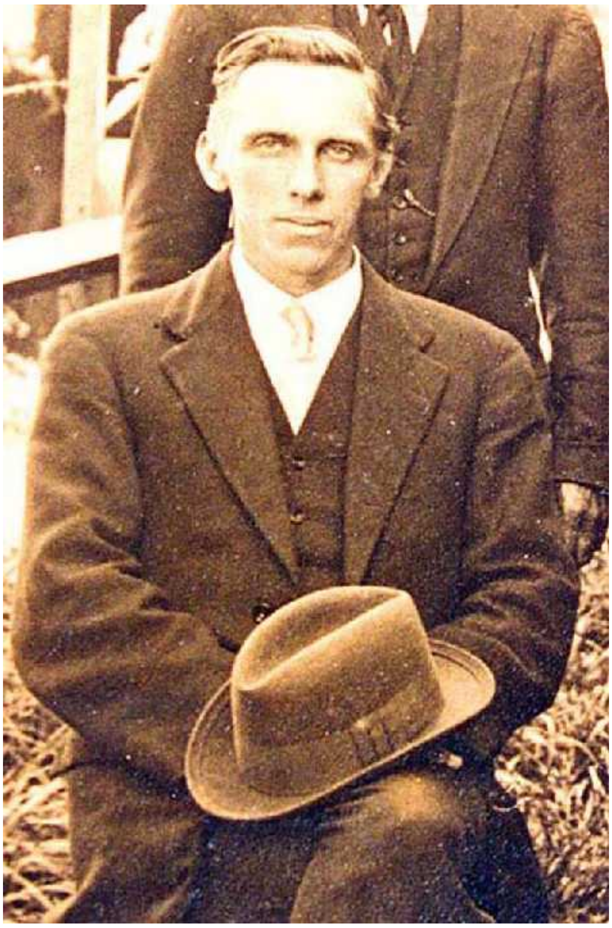


Figure 11. *J W Roberts*

Public Works Department engineers estimated that around 6,000 tonnes of steel would be required plus a large amount of ironbark for the large number of TTTOs for approaches to major bridges and for minor waterways. Even so, the proposed use of American bridges would keep the bridge cost to only about 10% of total costs. The engineer most responsible for achieving this was James Waller Roberts, Figure 11.

He was born in 1871 at Maryborough, Queensland and became a brilliant student, then went on to graduate in engineering with Honours at Sydney University. He joined the PWD Railway Construction Branch where he soon specialised in bridges. After this engineering unit was transferred to the Railway Department in 1917 to create the Way and Works Branch, Roberts was promoted to Principal Designing Engineer in 1920 through to retirement in 1933. The highlights of his career were, the steel trussed arch roof over the main concourse of Sydney Terminus/Central Station, all the North Coast Railway bridges and, the 1932 double-deck bascule bridge over the Clarence River at Grafton. At the age of 39 he wrote his definitive paper (Roberts 1910) on railway bridge engineering in NSW, relevant items are used in this Conference paper.

He began his paper with a brief reference to the British bridges, which has been expanded upon earlier here. Then he goes on to say *[edited slightly to fit the context of this paper]*,

The 1889 Hawkesbury River railway bridge was designed and manufactured in America and was the first use of steel for bridges, from which the American influence made itself felt. We find departmental designs of the Pratt type trusses using imported steel. In the present designs, the best features of the foregoing examples have been preserved and modifications made to the joints, a return to riveted rather than pinned joints.

He then refers to the long-term duplication of the single-track North Coast Railway and its effect on bridges, whereby he estimated that initial double-track bridges would increase the line cost by 75% and that duplication would be beyond traffic requirements for a good many years. However, he was mindful of the future in saying,

Improvements are constantly being made in designs, workshop practices and methods of erection. These advances may be available when the fitting times come.

Nearly a century later we can identify developments such as welded steel, pre-stressed concrete, box girders, heavy-duty mobile cranes and incremental launching as justifications of his stance. There are a large number of sites in NSW where adjacent old and recent bridges show the changing technologies.

As might be expected from an eminent bridge engineer, his paper has a long technical discussion on what types of bridges and their sizes to use at the multi-variable sites. After consolidating all the data, he made a rational decision to use three sizes of steel Pratt trusses, 61 m, 48 m and 36.6 m spans for the major river crossings, 20 m plate web girders for spans less than 30 m, and for the smallest waterways and approach viaducts 8 m TTTOs, Figure 12.

Initially, the steel bridges were fabricated and erected by contractors. Group1 comprised nine bridges from fabricators Clyde Engineering, Vale & Sons, Scrutton & Co. and Tulloch. Erectors were Carson Carey & Simpson, G Wilcocks and Smith Timms & Co. However, PWD engineers regarded the final erection costs too high after litigation settled compensation claims. PWD day labour was used for erecting the remaining fourteen bridges in two Groups. In Group 2, fabricators still supplied steelwork for seven bridges. Then in 1914 the State Government established the

State Dockyard at Walsh Island, Newcastle, which had the capacity to fabricate heavy structural steelwork, so it supplied Group 3, the last seven bridges.

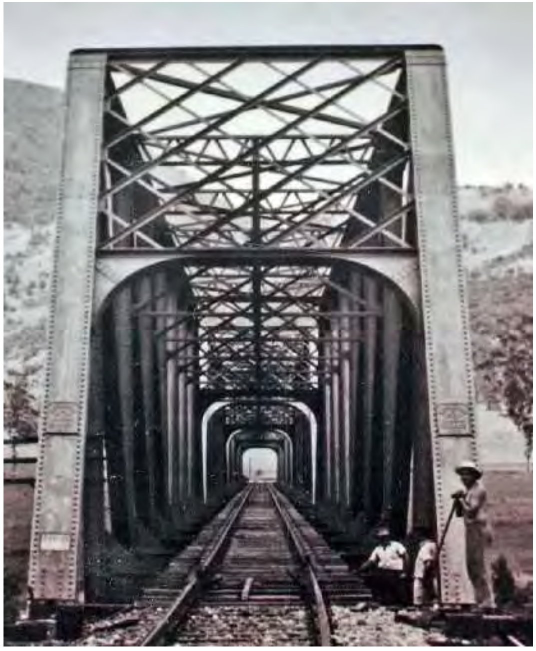
61 m truss at Paterson

48 m trusses over Hunter River

36.6 m truss over Dawson River

20 m Plate web girder, left
[Figure 12 continues]

TTTO approach viaduct



"Tunnel" view of an American through trusses

Figure 12. *Images of North Coast Railway bridges*

The final amount of steel bridges was 6,100 tonnes using mostly imported steel despite World War I. All steel bridges are still in service, again confirming J W Roberts' decision not to build double-track bridges. But all the TTTOs have been replaced by longer-span, welded, galvanized steel plate web girders, Figure 13.

Figure 13. *Replacing a TTTO viaduct near Wauchope in 1989*

A chronological list of 60 American type railway steel bridges with the numbers of trusses per location and the span lengths appears in the **APPENDIX**.

5. THE CLARENCE RIVER BRIDGE

The North Coast Railway was built in sections but not sequentially. Although the railway reached South Grafton in late 1915 it was an isolated 44km section from Glenreagh. Through running had to wait for sections between Macksville and Raleigh to be completed in 1923.

Figure 14. *Train ferry 'Swallow'*

But there was still the Clarence River to cross, so for the next nine years ferries transferred passengers across and the rolling stock too, on specially built ferries "*Induna*" and "*Swallow*", Figure 14.

The details of the river bridge are fully documented by Roberts (1932), key elements are presented here.

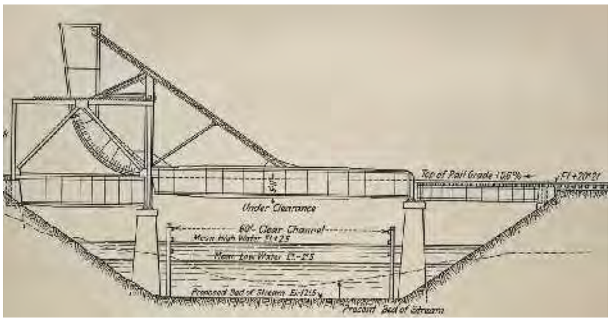
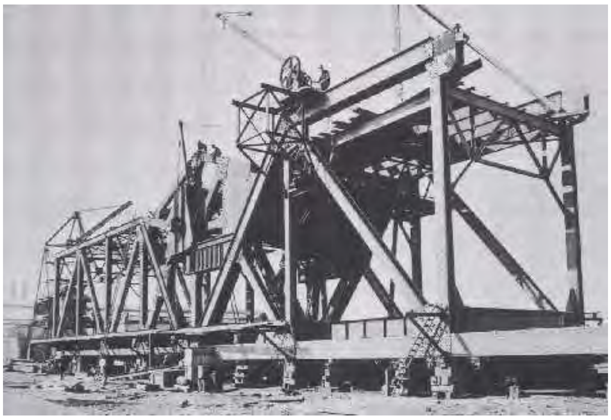
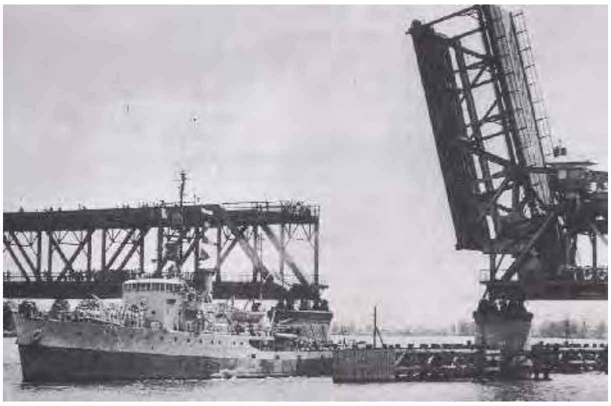


Figure 15. *Single-deck Scherzer bascule bridge*

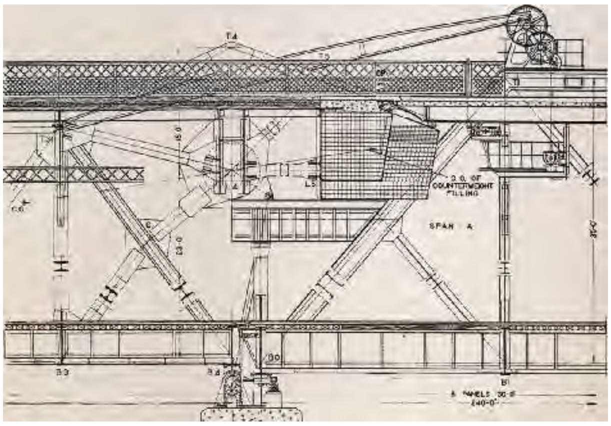
After World War I a design was prepared for a single-deck, rail-only bridge with a bascule span, Figure 15, for the river traffic. However, the Government decided in 1922 to have a road crossing as well, potentially doubling expenditure for two adjacent bridges. The simplest and cheapest arrangement was to put a road deck on top of the railway trusses, hence a double-deck bridge. Consequently, the single-deck bascule bridge, Figure 15, was unsuitable although it had a good feature whereby, as the rear portion tracked backwards it drew the span with it, ensuring a full width passageway. A specifically designed double-deck bascule span was required. Fortunately, the American patented Rall-type was suitable because its bascule truss could be modified for an upper deck roadway, Figure 16. The technical details are in Roberts' papers. The unit was assembled at Clyde, Sydney and operationally tested then dismantled and erected in its place in the bridge. It was officially operational on 8 May 1932, closing the gap with the 1930 section of the standard gauge railway Grafton to South Brisbane.



Trial assembly



Double-deck bascule span open



The Rall system operating mechanism

The operating mechanism has the pivot roller for the bascule span near mid-height of the truss. It rests on a short horizontal girder. As the upper pulling arm moves to the right, the top corner of the movable truss follows and the pivot roller moves to the right on the girder. The combined effect is for the moving span to swing up and retract thereby creating a large clear opening for river traffic. [This latter feature was basic to its selection]

Figure 16. *Double-deck Clarence River Bridge*

7

6. CONCLUSION

The North Coast Railway and the Clarence River Bridge have a unique place in Australia's railway and cultural history. The domination of British bridge technology had been abruptly severed in 1894 with the introduction of American bridges. They became the uniform types of railway bridges on the North Coast Railway which then became the NSWGR standard designs for the next 60 years (Fraser 1986). All the original steel bridges continue in service and now constitute an historic set of infrastructure of high heritage significance, as is the remaining stock of post-1894 timber truss road bridges.

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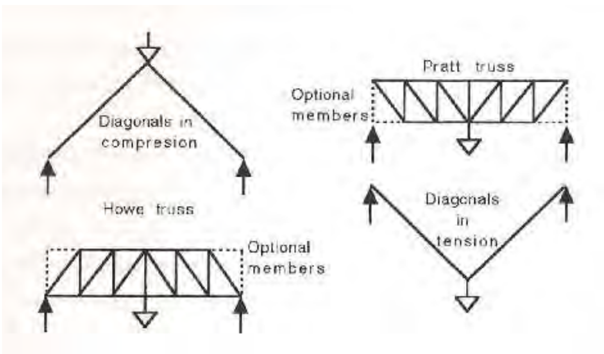
APPENDIX

Timber Howe truss



Timber Pratt truss

8

RAILWAY STEEL TRUSSES 1892 - 1925

Year	Location	No	Span feet	(m)
1892	Yass River, Yass	1	200	(61)
1894	Leycester Creek, Lismore #	3	120	(36.6)
	Coopers Creek, Bexhill #	1	120	(36.6)
	Wilsons River, Eltham #	1	120	(36.6)
	Pearces Creek, Pearces Cnr #	1	120	(36.6)
	Dunbible Creek, Dunbible #	1	120	(36.6)
1898	Ironbark Creek, Sandgate (r)	1	110	(33.5)
	Styx River, Newcastle (r)	1	73	(22.4)
	Liddell Creek, Liddell (r)	1	73	(22.4)
1901	Gwydir River, Gravesend	2	180	(54.9)
1902	Wollondilly River, Goulburn	2	120	(36.6)
	Hunter River, Singleton (r)	5	90	(27.5)
1903	Murrumbidgee River, Gundagai	1	200	(61)
1905	Richmond River, Casino *	1	180	(54.9)
1906	Namoi River, Manilla	2	180	(54.9)
1907	Nepean River, Penrith (r)	1	120	(36.6)
		4	193	(58.8)
1908	Glennies Creek, Glennies Creek (r)	4	129	(39.3)
1911	Hunter River, Oakhampton *	3	157	(48)
	Paterson River, Paterson *	1	200	(61)
	Parramatta Road, Homebush	2	73	(22.2)
1912	Ironbark Creek, Sandgate	1	126	(38.4)
	Parramatta Road, Lewisham	1	111	(33.8)
1913	Williams River, Dungog *	1	120	(36.6)
	Karuah River, Stroud Road *	1	120	(36.6)
	Avon River, Gloucester *	1	120	(36.6)
	Manning River, Mt George *	4	200	(61)
	Charity Creek, Mt George *	1	120	(36.6)
	Rocky Falls Creek, Mt George *	1	120	(36.6)
	Dingo Creek, Wingham *	1	120	(36.6)
	Gwydir River, Moree	2	120	(36.6)
	Mehi River, Moree	1	120	(36.6)
1913	Hunter River, Muswellbrook	1	157	(48)
1914	Boomi River, Mungindi	1	120	(36.6)
1915	Dawson River, Taree *	1	120	(36.6)
	Lansdowne River, Lansdowne *	1	120	(36.6)
	Stewarts River, Johns River *	1	120	(36.6)
	Camden Haven River, Kendall *	1	200	(61)
	Bellinger River North Arm, Raleigh*	3	157	(48)
	Bonville Creek, Bonville *	2	120	(36.6)
	Sherwood Creek, Kungala *	1	120	(36.6)
	Argyle Street, Moss Vale (r)	1	133	(40.5)
1916	Styx River, Newcastle (r)	1	73	(22.4)
1917	Hastings River, Wauchope *	3	157	(48)
	Wilson River, Telegraph Point *	2	157	(48)
	Cooperabung Ck, Cooperabung *	1	120	(36.6)
	Pipers Creek, Kundabung *	1	120	(36.6)
	Macleay River Kempsey *	3	200	(61)
	Wybong Creek, Sandy Hollow	1	157	(48)
1918	Lachlan River, Forbes	1	157	(48)
	Talbragar River, Elong Elong	1	120	(36.6)
1920	Railway Parade, Rozelle	1	90	(27.4)
	The Crescent, Annandale	2	108	(32.9)
	Wentworth Park Road, Glebe	1	75	(22.9)
1921	Coxs River, Wallerawang (r)	1	57	(17.4)
1923	Nambucca River, Macksville *	2	157	(48)
	Bellinger River South Arm, Raleigh*	3	200	(61)
1924	Orara River, Glenreagh	1	157	(48)
	Prospect Creek, Carramar	1	120	(36.6)
1925	Macquarie River, Dubbo	2	120	(36.6)
	Illawarra Lines, Sydenham	1	123	(37.5)
	Total	60		

= Murwillumbah Line   * = North Coast Railway   (r) = replacement bridge

(Source – *Bridges Down Under p66*)

3rd Australasian Engineering Heritage Conference 2009

Remnants of Early Hydraulic Power Systems

J W Gibson MA (Syd), MIE Aust. & M C Pierce BE (Elec), FIE Aust.

SUMMARY: *This paper briefly outlines the development of water hydraulic power systems and devices during the nineteenth century and then describes a range of extant system elements from Australia and New Zealand. The significance of this early motive power technology is underlined by the many end-use applications that evolved and further work in identifying, recording and where practicable, conserving extant remnants is advocated.*

KEYWORDS: *hydraulic, power, historic, heritage*

1. THE DEVELOPMENT OF HYDRAULIC POWER

The first practical hydraulically operated machine was the hydraulic press, invented by Joseph Bramah in 1796. Bramah's press embodied the principle originally demonstrated by Pascal in 1647, where-in fluid pressure created by applying a force to a small area plunger in a closed cylinder can be used to act on a larger area plunger to produce a correspondingly larger force if the fluid spaces in the two plunger cylinders are connected by a pipe. In Bramah's machine the larger plunger or ram operated the moving platen of the press.

Bramah went on to conceive other ideas for transmitting and using hydraulic power, most notably as documented in his 'omnibus' patent specification of 1812, however these ideas were not taken up in his lifetime (McNeil 1968). It was not until 1840 that William Armstrong – later knighted for his pivotal work in improving armaments – developed his ideas for a hydraulically operated crane based on the hydraulic jigger. The hydraulic jigger comprised a ram in a closed cylinder arranged with multiple pulley sheaves at each end so as to multiply movement of the free end of a chain or rope wound around the sheaves when a pressurised fluid, normally water, was admitted into the cylinder. (The hydraulic jigger operated in the reverse manner to the conventional block and tackle).

A 5 ton (5t) hydraulically operated crane based on Armstrong's design was installed on a Newcastle-on-Tyne wharf in 1846 (Armstrong 1858). Its success led to similar hydraulic cranes being installed for wharves and railway yards in other places in the UK. Figure 1 shows a diagram from Armstrong's 1858 paper of an early hydraulic crane with hydraulic jiggers used for both the hoisting and slewing motions. The source of the pressurised fluid for these early hydraulic cranes was the town's water supply. Water pressures of up to 90 psi (600 kPa) could be obtained in this way to act on the ram within the individual hydraulic jiggers, with control by way of lever operated three-way valves.

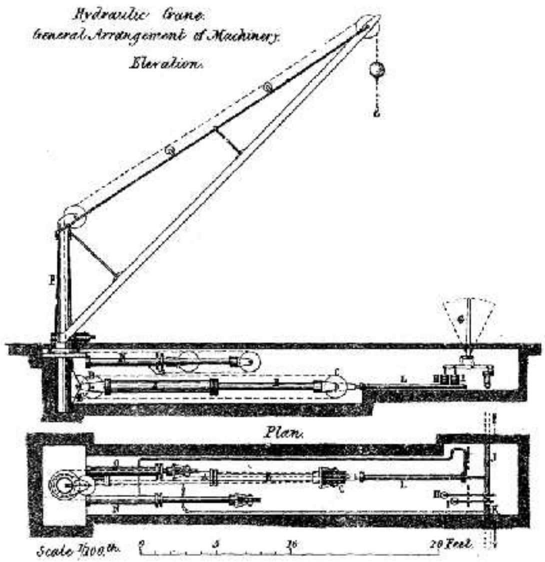


Figure 1. *Armstrong Hydraulic Crane.*

Although hydraulic cranes operated from the public water supply mains worked tolerably well, problems arose with pressure variations due to draw-off by other water users. Notwithstanding this, some installations continued to utilise mains pressure water sources, including some early hydraulic lifts. Armstrong's first solution to the variable pressure difficulty was to arrange for an independent elevated tank or 'water tower' into which water was pumped and from which the hydraulic plant was then powered. In 1851 Armstrong is credited with reinvention of the hydraulic accumulator used in conjunction with high-pressure plunger pumps, a system originally proposed although not implemented by Bramah in 1812. In this device a ram arranged in a vertical closed cylinder is loaded by dead weight ballast, with energy able to be stored by upward movement of the ram and recovered on its descent. Thus, the accumulator acts as a pressure sustaining device between the high-pressure pumps and the hydraulically operated machines connected to the system. (Armstrong 1858; Armstrong 1877).

Figure 2 from Armstrong's 1858 paper illustrates the construction of the hydraulic accumulator.

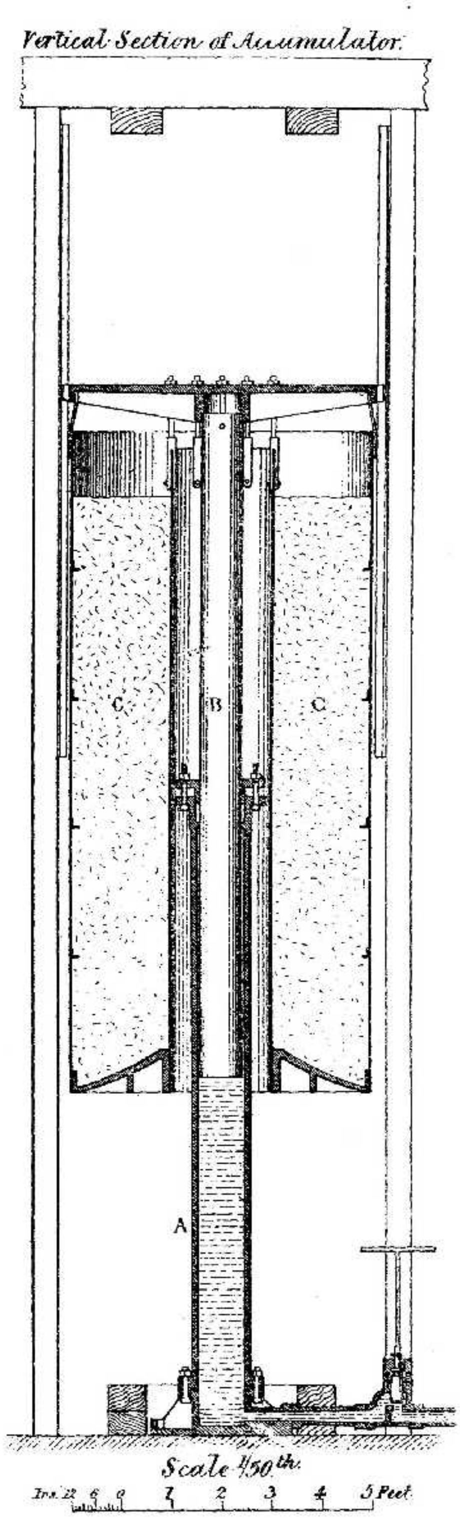


Figure 2. *Armstrong's Hydraulic Accumulator.*

By arranging to regulate the pumping rate to maintain the accumulator ram between its upper and lower travel limits, a constant pressure is sustained and short term peaks and troughs in water demand are accommodated by movement of the ram to utilise its water storage capacity. Although the accumulator could not offer the storage volume of an elevated tank, its major advantage was in permitting a much higher operating pressure with a consequent reduction in size of pressure mains and hydraulic machine cylinders, and also a marked improvement in operating efficiency.

The success of the hydraulic accumulator led to many more installations with an operating pressure in the range of 600 to 700 psi (4.1 to 4.8 MPa) becoming 'standard'. With the introduction of high-pressure hydraulic power, the range of hydraulically operated machines and equipment expanded rapidly. Although hydraulic power was ideally suited to linear motion machines based on the ram and cylinder combination, such as utilised with the hydraulic jigger, rotary hydraulic engines were developed for operating haulage capstans and moving the lift sections of bascule and other bridges. Pelton wheels or other water turbines were also occasionally used to drive electric generators.

Armstrong's Elswick (UK) Hydraulic Equipment Company manufactured high-pressure hydraulic machinery for a central power plant system to supply hydraulically operated coal loading cranes for the Port of Newcastle in Australia. This facility was engineered by the NSW Public Works Department under Edward Moriarty. It went into service in 1877 and operated continuously for the following 90 years (Bairstow 1986; Cockbain 1998).

The first public hydraulic power system commenced operation in Hull in the UK in 1876 (Pugh 1980). The Hull hydraulic power system had a central steam operated pumping station with some 4 km of 6 inch (150 mm) cast iron pressure mains buried beneath city streets. With this system customers could connect to the company's main and purchase high-pressure water to operate hydraulic machines at their individual premises. That is, the system was an early motive power distribution utility available to individuals and companies whose premises were near where the hydraulic company's mains were routed.

The Hull public power scheme, although modest, acted as a proving ground for the very much larger London system that followed it. The City of Liverpool followed London with a public hydraulic system that commenced operation in 1885 (Pugh, 1980). In July 1889 a public hydraulic power system was inaugurated in Melbourne by the Melbourne Hydraulic Power Company, making it the fourth such system in the world (Pugh 1980; Pierce 2008). It operated through to 1967. A similar public utility service for Sydney commenced operation in 1891 and operated until 1975.

The use of water conveyed in pipes under high-pressure offered a convenient means of transmitting mechanical energy from a steam engine(s) driving plunger pumps to distant locations at a time when 'steam was king'. In this way, motive power could be delivered to end-use devices at distances of up to 10km with an efficiency of around 90% (Pugh 1980). A central pumping plant could be arranged to power many distributed end-use devices within an industrial site such as docks, railway workshops, etc, or in a city context where the high-pressure mains were laid under the streets, for powering passenger lifts in tall buildings. As well as convenience and an 'economy of scale' by using large central plant, the atmospheric polluting effect of a multiplicity of small steam boiler plants could be reduced along with avoiding the cost to operate and maintain each such installation. These latter considerations were particularly pertinent for the public hydraulic power utilities serving urban areas in the late 19th and early 20th centuries.

Figure 3 illustrates a distributed hydraulic power system with central plant consisting of a steam engine or other prime mover driving high-pressure pumps, a pressure sustaining and controlling device in the form of a hydraulic accumulator connecting, via HP piping, to a diverse range of end-use hydraulically operated machines and devices. In the following sections, each of these elements is discussed with examples of remnants from a range of locations that are known to the authors.

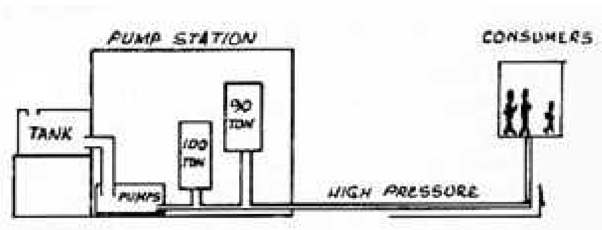


Figure 3. *Typical Hydraulic Power System.*

A more detailed diagram for the system is provided in Appendix A.

2. HIGH PRESSURE PUMPING PLANT

Two high-pressure pumps remain within the NSW Government Railways workshops, now Australian Technology Park, at Eveleigh in Sydney. They are located in a pump-house south of Bay 2 of the workshop buildings. One is a twin cylinder steam driven Fielding and Platt engine/pump, still in excellent condition – see Figure 4. The other is an electrically driven three-cylinder Hathorn pump. A pressure gauge on the wall suggests a red-line hydraulic pressure of 2500 psi (17 MPa). The Fielding and Platt steam engine pumping set is now a quite rare example of what was originally the norm for high-pressure hydraulic power system pumping plant with the plunger force pumps directly connected to the steam engine crossheads.

Figure 4. *Fielding & Platt HP Pump.Chullora.*

The use of water hydraulic power equipment in many heavy industrial facilities well into the twentieth century sometimes led to reciprocating steam engine high-pressure pump sets being replaced by electrically driven pumps, although in most cases the pumps themselves remained as multiple cylinder positive-displacement pumps as used by Armstrong from the 1850s. This appears to apply to the electric motor driven three-cylinder Hathorn pump at Eveleigh. For later installations, electrically driven pumps could have been employed from the outset. Electrically driven, three-cylinder positive displacement pumps for on-site hydraulic services remain extant at Sydney's Garden Island Naval Stores building, Chullora NSW railway workshops and in the power house of the former dockyard on Cockatoo Island. Refer to Figure 5.

Figure 5. *Electrically driven HP Pump, Chullora.*

3

An independent hydraulic power system that served the wharves of Walsh Bay in Sydney utilised a twin cylinder double-acting reciprocating pump driven by a 65 HP (48 kW) electric motor. It still exists as a feature in a restaurant on ground level in the Central Wharf Stevedoring building (wharf 8/9). The system supplied hydraulic power to lifts, wool presses, and possibly to wharf conveyors.

Figure 6 shows a three-cylinder Johns & Waygood hydraulic pump set at the historic Hobart wool store – now an apartment hotel – were it is was most likely used to power water hydraulic wool baling presses. The pump has a pair of fast and loose pulleys for a flat belt drive from an engine, either directly or through a countershaft. The crankshaft for the three plunger type pumps is in turn driven through reduction spur gearing. The suction and delivery valves are mounted on the outward end of the pump cylinders with the interconnecting pipework terminating in a two-bolt oval flange characteristic of water hydraulic power systems.

Figure 6. *Johns & Waygood HP Pump,Hobart.*

Figure 7. *Accumulators, Eveleigh, Sydney.*

Figure 8. *In situ Accumulator, Walsh Bay, Sydney. (Photo – M Doring)*

3. HYDRAULIC ACCUMULATORS

Hydraulic accumulators, whilst all embodying the basic functional configuration used by Armstrong and illustrated diagrammatically in Figure 2, took on a variety of forms and construction details.

Figure 7 shows the common cylindrical ballast container surrounding the central hydraulic cylinder and ram at the former Eveleigh NSWGR workshops. A very similar outdoor accumulator was used at the Western Australian Midlands railway workshops. The former main pumping station building of the Sydney Hydraulic Power Company – now reused as a tavern – still contains a pair of indoor cylindrical form accumulators. In each case, the annular cylinder enclosing the accumulator ram was filled with crushed rock, scrap iron or other ballast material which for a 700 psi (4.8 MPa) nominal system pressure typically totalled around 100 t, acting on a ram of around 450mm diameter and having a vertical stroke range of about 6 metres.

The accumulator originally installed for the independent hydraulic power facility at Sydney's Walsh Bay wharfs utilised a rectangular platen to support a brickwork ballast instead of the more usual cylindrical style. Figures 8 show this accumulator in its original location. It is currently in a new nearby location where it has been reconstructed and interpreted. The cylinder and the upper portion of the ram are clearly visible.

Yet another accumulator design is illustrated in Figure 9 near the Brakehead of the former Denniston Incline on the west coast of the South Island of New Zealand. It was reportedly used for the hydraulic crane that was once adjacent to the Top Brake and also for the hydraulic actuators on the coal bin discharge chutes (Petchey, 2007). (The photograph dates from 2005 and the item may have since been conserved as a part of the site rehabilitation works by the NZ Department of Conservation).

The position of the accumulator ram was normally used to control the high-pressure pumps to match the external water demand by the connected end-use equipment. In the case of a steam engine driven pump, a mechanical linkage from the accumulator ram could be used to continuously adjust the engine speed and thus the pumping rate in a form of proportional feedback control. For electrically driven pumps, a wound rotor induction motor was commonly used with limit switches operated by the accumulator ram movement arranged to switch 'in' or 'out' rotor circuit resistors and thus adjust the pumping rate in several discrete steps. The accumulator at Walsh Bay has the remnants of an electrical limit switch system.

Figure 9. *Denniston Hydraulic Accumulator, NZ*

For some large sites utilising water hydraulic power and for public utility systems, the high-pressure pumping plant and associated accumulators were housed in a purpose designed, and sometimes ornate, building. The former central plant building for the Newcastle (NSW) harbour hydraulic power system with its twin accumulator towers is now the sole readily visible remnant of this important maritime industrial installation. The Sydney Hydraulic Power Company main pumping station building in Pier Street Darling harbour has also survived and has been recycled for another use as mentioned above.

4. HYDRAULIC HOISTS & CRANES

Hydraulic hoists and cranes typically used the 'hydraulic jigger' as developed in the UK by Armstrong for his first c1850 hydraulic crane. Another common use of a single hydraulic jigger was for goods hoists to lift materials to and from upstairs warehouse floors. These were commonly called 'whips'.

Melbourne's c1880 Rialto building – now a prestigious hotel – has two hydraulic jiggers mounted vertically on the west external wall. One of these is depicted in Figure 10. Wire rope, now removed, originally passed around the three upper and lower sheaves on the jigger. The free end then ran over a pulley in a pediment over the uppermost floor access doorway to the lifting hook. The two whips were powered from the Melbourne Hydraulic Power Company public supply mains and were used to lift goods from a basement level laneway to the access doorways on any of the upper floors (Pierce 2008). The Rialto building is heritage listed and the remnants of the whip hoists have been retained and preserved and, in recent times referred to in interpretive signage about the building. They are about the only readily visible reminders in Melbourne of the once dominant hydraulic motive power utility.

Figure 10. *Rialto Building Hoist (Whip), Melbourne.*

Similar remnants of hydraulic whips can be seen on the front wall of Campbell's Stores in The Rocks; part of Sydney's waterfront, see figure 11. Here again, the heritage status of the buildings and the precinct should ensure their retention. Similar to those at the Rialto in Melbourne, the Campbell's Stores whips were connected to the Sydney Hydraulic Power Company's mains for which the owner paid a service fee and a water usage charge. In each instance a three-way valve, visible in the photographs, was operated by a rope passing close to the respective floor access openings which controlled the admission of water to raise the ram and thus lift the suspended load or conversely to release the water allowing the ram to retract and thereby lower the suspended load.

Figure 11. *Whip on Campbell's Stores, Sydney.*

Another hydraulic whip hoist with its lifting rope, upper pulley and hook still in situ is in the courtyard of the Argyle Stores, also in The Rocks. The whip is all that remains of a small private hydraulic system. This whip was made by Tannett Walker (Leeds, UK) in 1885 and was installed by Mr. Isaac Ellis Ives following the rebuilding of the south wing c1878. Isaac was Mayor of Sydney between 1897 and 1898. The system originally comprised a small gas engine driving a small three-cylinder pump. Pressure was controlled by an accumulator and fed to the whip on the wall of the south wing, and at least one, possibly two, other lifts inside the north wing. The Argyle Stores whip recently had significant conservation work carried out by the first author for its owner, the Sydney Harbour Foreshore Authority (Gibson 2006). Other extant whip hoists are located in the Naval Stores Building on Garden Island in Sydney, but these are unfortunately not accessible to the general public.

There are fewer examples of extant hydraulic cranes known to the authors. Figure 12 shows a fixed jib hydraulic crane at the Newport railway workshops in Melbourne. It utilised a hydraulic ram jigger mounted on the crane mast with the lifting rope reeved through pulleys to give a 2:1 lifting ratio. As the cylinder rotated with the manually slewed crane, connection to the site high-pressure hydraulic mains, which operated at 1700psi (11.7 MPa), was via a swivel joint at the masthead (Doring 1988).

The Denniston Incline mentioned above had a hydraulic crane near the top brake (Brakehead) and at the bottom Conn's Creek rail siding. Much of the latter crane has survived and is now conserved. It appears that the pressurised water supply for this crane was from an elevated storage on the nearby hillside, reminiscent of the early Armstrong crane using relatively low-pressure water. Also in this case, a double-acting piston in a large diameter cylinder was used rather than the usual ram and smaller diameter cylinder common to high-pressure systems. (There is some evidence that the components were improvised from steam locomotive parts). The vertical cylinder is fixed adjacent to the crane and the lifting rope was reeved for a 2:1 ratio and arranged to pass up the axis of the rotatable mast. Slewing of this crane was handled manually.

Figure 12. *Hydraulic Crane Newport Railway Workshops. (Photo – C & M Doring)*

5. GOODS AND PASSENGER LIFTS

Whilst some of the earliest lifts or 'elevators' were arranged using mechanical drives from engine plant, hydraulic actuators with their inherent linear motion were well suited to the task. The first hydraulic lifts appeared around 1865 and typically utilised low-pressure water from the town mains supply or from an elevated storage tank, although booster pumps driven by a gas engine or similar were sometimes utilised to obtain sufficient operating pressure (Gavois 1983). When public hydraulic power systems were established in some major cities, including Melbourne and Sydney, in the latter part of the nineteenth century the availability of high-pressure water hastened the adoption of hydraulic lifts which in turn facilitated the construction of taller commercial buildings.

The two main types of hydraulic lift were the suspended type using variants of the hydraulic jigger to control the lifting ropes, and the direct acting where the hydraulic ram pushed the lift car from below. For the former arrangement, the hydraulic cylinder could be arranged either vertically in a part of the lift shaft or horizontally in the building basement with suitable rope reeving to the head pulleys from which the car was suspended. The direct acting hydraulic lift on the other hand required a shaft below the lowest landing of the same depth as the height to the uppermost floor to be served by the lift.

Figure 13 shows a c1900 mains pressure hydraulic lift at the former c1824 Government Bond Store on Hobart's waterfront. The external goods lift, which served three floors in the building, was manufactured by the Austral Otis Company and used the 'Hales' standard hydraulic system that originated in the USA. The vertically mounted hydraulic cylinder was of relatively large diameter in view of the low operating pressure and utilised a double-acting piston with dual piston rods that were normally in tension. Operation of the water control valve at the base of the cylinder was by a rope loop that could be pulled by the operator from the lift platform. This historic hydraulic lift was restored by the then Lift Manufacturers Association of Australia from 1982-88 and is still extant, although safety regulations have precluded its continued operation or demonstration.

At No. 1 Kent St, Sydney a hydraulic passenger lift was reconstructed in the atrium of the refurbished building c1992. This lift was originally connected to the Sydney Hydraulic Power Company high-pressure mains. It is ostensibly still an operating lift, in that the hydraulic cylinder is connected to a modern oil based hydraulic system, however like the Hobart lift above, its continued use has been prevented by current lift regulations.

Figure 13. *Goods Lift, Hobart Bond Store building (Photo – B Cole)*

An in situ passenger lift car and hydraulics remain in the old AGL Gasworks building at the end of Gas Lane, extending to Hickson Rd, in Sydney. The lift shaft has been closed off at each floor to enable productive use to be made of the space, but the passenger car, the hydraulic cylinder, and the counterweight still remain intact. The lift valves were operated electro-mechanically, before this lift went out of service c1975. The car is at the bottom of the shaft at the Hickson Rd, level. A unique feature of this passenger lift is that the cylinder has, cast in along its length, the name of its maker – 'Sydney Hydraulic Power Co. Ltd'.

The former Melbourne Tramways & Omnibus Company (later MMTB) c1895 head office building at 673 Bourke Street originally contained three hydraulic lifts powered from the MHPC mains. The main lift, enclosed in a mesh-metal 'shaft' in the foyer stairwell was later converted to DC motor operation. However, a goods lift that originally served from the basement to the second floor still has its hydraulic cylinder and associated equipment in situ on the sidewall of the lift shaft. It is hoped that this important remnant of the era of high-pressure water hydraulic lifts in Melbourne will be preserved in some meaningful way.

The movement of large quantities of coin between street level and the strong rooms (generally below ground level) by the banks was facilitated using hydraulic bullion/coin lifts. These tended to be bigger than passenger lifts but limited in travel height. In one of the Sydney banks the lift floor is 2m x 3.5m with two sets of heavy steel access doors. The steel framework has rolled into it "Dorman, Long & Co. Middlesbro" potentially dating it around the 1930s. The lift is no longer used.

Figure 14 shows the controls of another bullion lift located in a former Sydney bank building, now converted for retail use, This lift has its cylinder and counterweight in situ, as well as the lift car, but recent building work has left it covered in rubble. This lift had been converted at some stage to electrical control. The electro-hydraulic control system including what appears to be a time clock appears to be complete, and much of the pipe-work is still in place. There was no evidence of a pump, but the presence of SHPC control valves behind the building suggests a connection to the SHPC system.

Figure14. *Electric Control for Bullion Lift.*

6. TEXTILE BALING PRESSES

A large number of hydraulically operated wool presses were installed in many of the wool stores along the shores of the working harbour in Sydney, and in Ultimo/Pyrmont. One extant example is in the Dalgety wool stores building, now apartments, in Jones Street, Pyrmont. To gain sufficient force to press bales, particularly high-density bales for export, the hydraulic pressure supplied from the SHPCo mains was increased about fivefold by an hydraulic intensifier (Figure 15).

These devices essentially comprised a pair of coupled rams with cross-sectional areas in the ratio of the desired pressure step-up ratio, and arranged in 'low' and high pressure cylinders respectively. The output of the intensifier was then fed into the wool press hydraulic ram to perform the baling operation (Figure 16). The wool press depicted was manufactured by Austral Engineering Co. in Melbourne, with steelwork from Dorman, Long & Co.

Figure 15. *Intensifier for Wool Presses, Sydney.*

Other hydraulic wool presses have been recorded in the nearby Farmers and Graziers wool store and such equipment was widely used elsewhere for the baling of textile fibres. Where a public high-pressure hydraulic utility service was not available, the site would require its own in-house high-pressure pumping plant and accumulator. An example of the former is mentioned above for the historic Hobart wool store.

Figure 16. *Wool Baling Press, Sydney*

7. THEATRE STAGE MACHINERY

Three Melbourne theatres were fitted with hydraulically operated elevating platforms for a Wurlitzer organ console and for the theatre orchestra. The Capitol Theatre in Swanston Street was the first to open in 1924, followed in 1929 by the State Theatre - now called The Forum – and the Regent Theatre. Typically, the organist and/or an orchestra dramatically rose up from the stage basement to open the evening's entertainment and then sunk back out of sight at the commencement of the feature film. The State Theatre in Sydney was similarly equipped and opened later in the same year.

Both of the State Theatres in Melbourne and Sydney still have their respective hydraulic organ console and orchestra platforms in situ, although they have been out-of-service for at least sixty years. Figure 17 shows the ram and crosshead for the orchestra platform in Sydney's former State Theatre.

The single hydraulic ram to raise the assembled orchestra from the stage basement into the theatre has its cylinder crosshead supported on steel beams above a rectangular shaft cut into the native rock to accommodate the full length of the cylinder (about 3.6 m). In its rest position, with the ram retracted, the platform underframe is supported on masonry piers. The three-way valve controlling the admission of high-pressure water into the ram cylinder to lift the platform, and to drain it for lowering, was fitted with large DC solenoids to enable remote electric operation. An electric limit-switch and a direct mechanical linkage from the ram crosshead were arranged to prevent inadvertent over-travel.

Figure 17. *State Theatre Orchestra Pit Ram, Sydney.*

The organ console platform is housed in a cylindrical concrete 'shaft' about 2 m in diameter and has a smaller direct-acting hydraulic ram with the cylinder crosshead supported off steel beams spanning the shaft underneath the platform. Again, DC solenoid actuation of the three-way valve permitted remote operation of the organ console lift.

The Melbourne theatres' elevating organ console and orchestra platforms were operated from the public hydraulic power utility with service connections to the under-street mains. The State (Forum) and Regent theatres are believed to be the last new services to be connected to the public hydraulic power system which by then was owned and operated by the City Council's Hydraulic Power Department. Similarly, the Sydney State Theatre hydraulic equipment was supplied from the Sydney Hydraulic Power Company's high-pressure mains.

8. METAL WORKING MACHINERY

Water hydraulic power was once widely utilised for metalworking machinery in large 'heavy engineering' facilities such as railway workshops and ship building yards. Typically such facilities would include an in-house central high-pressure pumping plant and associated accumulator with high-pressure mains then routed around the site and individual workshop buildings for supply to hydraulically operated machines and appliances. Some of these sites are referred to above in relation to extant high-pressure pumping plant and/or accumulators.

There are quite a number of hydraulically powered machines remaining on display at the former Eveleigh NSW Government Railway Workshops, now Australian Technology Park (ATP). These include the Davy 1500 ton press and intensifier in Bay 1; two Allen Strikers used for forging operations in Bay 2; a platen press also in Bay 1; a hydraulic spring disassembler; an Ajax continuous forging machine, etc. The large Davy forging press used hydraulic power in conjunction with steam cylinders (Butcher 2004).

The Midlands Railways workshops in Perth, Western Australia, likewise utilised hydraulically powered machines including a 1000 t Fielding press (Figure 17), other forge presses, spring presses and hydraulic riveters.

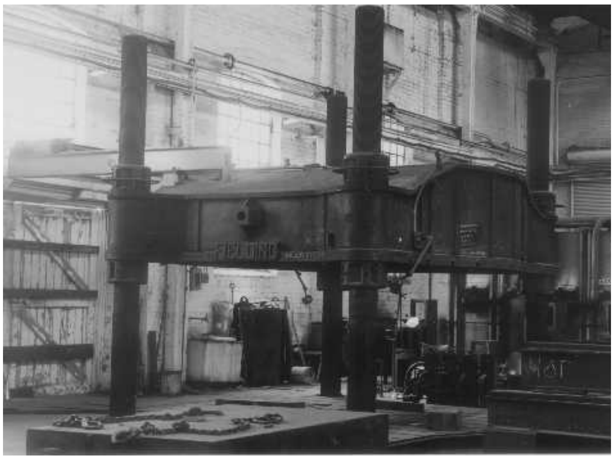


Figure 18. *Fielding Press, Perth. (Photo – C & M Doring)*

Similarly, when surveyed in 1888, the Victorian Railways very extensive Newport Workshops had a range of hydraulically powered machine remnants, including the 2t hydraulic jib crane mentioned earlier along with various presses, riveters, etc. (Doring 1988). Although some items had been partially disassembled, the Heritage Listing of the workshops site will hopefully preserve these machine tools from an earlier age.

The Cockatoo Island dockyard in Sydney Harbour also distributed high-pressure water from pumps located in the central powerhouse for use by hydraulic riveters, presses, plate bending machines and other heavy machines associated with shipbuilding. A large platen press and a heavy plate-bending machine are readily visible to visitors to the site but are no longer protected by an enclosing building.

9. HYDRAULIC POWER PIPING SYSTEMS

Both the Melbourne and Sydney public hydraulic power systems had an extensive network of high-pressure pipes buried under CBD roads and footpaths, a majority of which remain, albeit out-of-sight. The Sydney system had about 80 km of piping at its peak. The mains were typically 6 inch (150 mm) and 4 inch (100 mm) thick-walled cast iron pipes with two-bolt oval flange joints incorporating a resilient gutta-percha seal ring. Smaller pipes including those for individual customer services were commonly of thick steel tubing. High-pressure valves for isolating mains sections and for customer take-offs were identified by cast-metal valve pit covers set flush into footpath and roadway pavements (Figures 19 and 20). Fortunately, from a heritage perspective, many of these remain in both Melbourne and Sydney streets. The former bear the identification 'Hydraulic Power Co.' or (post 1925) 'Hydraulic Power Dept.', and the latter 'SHPC' or 'HPCo.' About 150 remain in Sydney's streets and at least half that number in Melbourne

Figure 19. *Valve Cover, Melbourne.*

Figure 20. *Valve Cover, Sydney.*

Some exposed 4" (100mm) main exists in Hickson Rd, Sydney (near High St.). Oval flange joints for each section of this pipe have 'SHPCo.'. cast into the side of the flange.

High-pressure hydraulic piping, valves and other fittings are also in evidence to a greater or lesser extent at most of the other places that have already been mentioned in relation to extant hydraulic power system remnants.

Figure 21. *HP Joint on Remnant 4" Main, Sydney.*

10. OTHER INSTALLATIONS

Bank Doors

Several of the prominent Banks in Sydney's central business district had their external doors operated by hydraulic power from the Sydney Hydraulic Power Company system mains. Typically, these doors were up to 6 m high and 3.5 – 5.5 m wide (Figure 22). They were constructed of steel frames clad with rolled bronze sheeting. The operating system on some was through a direct acting piston, with the cylinder in the basement extending down into a pit below the door to enable full travel. A typical cast iron piston of the period was 100 mm diameter, with the cast iron cylinder 180 mm diameter providing a lifting capacity of up to 4 ton.

Figure 22. *Hydraulically operated Bank Doors, Sydney.*

The alternative arrangement was for a combination of hydraulics, pulleys and counterweights to be used. One of the doors on the Commonwealth Bank in Pitt St still operates on this format, although it has been converted to oil operation. The saving here is in the reduced length of travel of the piston, the fact that the shorter cylinder is mounted on the wall behind the door in the basement, and the reduced piston diameter for similar load capacities. The control valves (3-way) in each case are located on the foyer level of the building.

Disappearing Guns

William Armstrong, who pioneered the development of water hydraulic power systems and related equipment from the middle of the nineteenth century, was later also involved in the development and manufacture of armaments and for which he subsequently received a knighthood. In the early1880s Armstrong combined the two technologies in his disappearing gun carriage which utilised a hydro-pneumatic system to absorb the recoil of his 6-inch and 8-inch guns. In this way the energy could be reused to later return the heavy gun to its elevated firing position after it was reloaded out-of-sight within the gun emplacement. The arrangement afforded greater safety for the gun crew and the gun itself was only briefly visible to the enemy above the emplacement parapet when it was elevated for firing.

Disappearing guns were installed in many British Empire coastal defence fortifications from around 1885 as a precaution against a then perceived possible Russian offensive. In Australia these included fortifications for Port Phillip Bay, Sydney Harbour, Brisbane River and in New Zealand, for Auckland, Wellington, Lyttelton and Dunedin harbours.

Figure 23. *Disappearing Gun, Taiaroa Head, Dunedin.*

The recoil hydro-pneumatic cylinder that connected to the gun trunnion was both massive and complex, with multiple internal chambers and flow control valves. It operated at pressures up to 1600 psi (11 MPa) (Harding 1896). A multi-cylinder manually operated pump was used to initially charge the cylinder and/or to top-up the pressure between firings. In practice, the added complexity of the disappearing gun carriage was soon found not to justify its originally presumed benefits and they fell out of favour for subsequent defences.

Remnants of the disappearing carriages, with and without their guns, exist at many of the above mentioned former coastal defence installations, but Dunedin harbour has the distinction of having a fully restored 6-inch disappearing gun in situ at Taiaroa Head fortifications on the Otago Peninsula (Figure 23).

Water Hydraulic Braking

New Zealand's famous c1880 Denniston Incline for lowering loaded rail wagons from coal mines on the Mt Rochfort plateau to the west coast for shipment out of Westport on the South Island made use of high-pressure hydraulic pump engines for purposes of braking. The incline was constructed as two contiguous sections with each one using twin winding drums on a common shaft arranged to lower a loaded rail wagon down the incline and at the same time pull up an empty wagon. The speed of operation was controlled by double-acting hydraulic engines driven by cranks from the winding drum shaft, with the water flow rate from one side to the other of the cylinders regulated manually by the operator. Provision was made to bleed-off the resultant hot water and to replace it from a nearby tank. The Denniston Incline with its two rope haulage sections operated up until 1967 (Figure 24).

Figure 24. *Remnants of Middle Hydraulic Brake, Denniston Incline. NZ. (Photo – J Staton)*

11. CONCLUDING REMARKS

The development of high-pressure water hydraulic power systems and equipment from the middle of the nineteenth century extended the reach of the steam engine by being able to efficiently transmit energy for motive power purposes at distance ranging up to ten or more kilometres and opened the way for a wide range of hydraulically powered devices. These included cranes and hoists, goods and passenger lifts, textile baling presses, theatre and stage machinery and heavy workshop machines and tools. A central pumping station could be used to serve a large industrial facility or a city area, with the motive power conveniently conveyed in pipes. No longer was it necessary to have engines close to each end-use device or line shafting and open belts to serve a group of powered equipment.

The development of electricity generation at central stations and distribution by wires and cables for motive power applications challenged water hydraulic power systems from the latter years of the nineteenth century and ultimately superseded it. However, many water hydraulic systems and end-use devices remained in-service well into the twentieth century with some only ceasing in the last quarter. Nevertheless, once retired from service much of the former long serving equipment ended up as scrap metal. It is therefore important to identify, record and if practicable conserve significant remaining examples of this phase of motive power transmission and end-use applications. This paper has briefly described some extant remnants but the authors would be pleased to receive information on other sites where hydraulic plant and equipment still exists.

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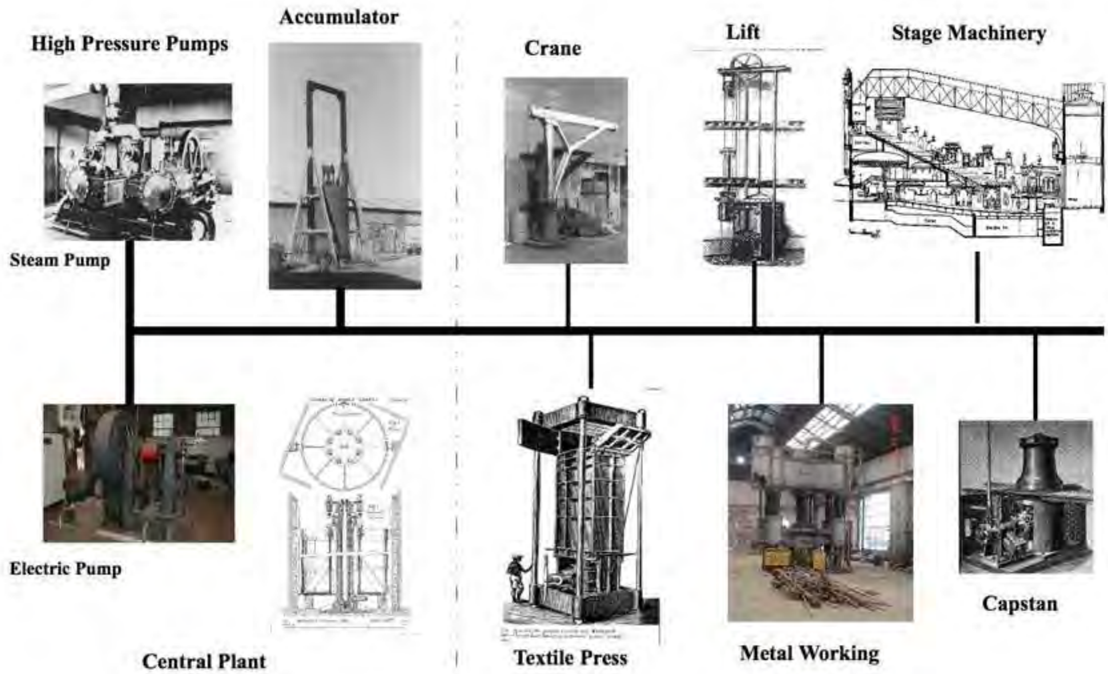
Note: Unless otherwise indicated photographs are by the authors.

Appendix A



The Hydraulic Power System.

The Otago Central Rail Trail: Preservation of Heritage Sites through Development for Visitor Use. A Case Study of the Visitor and Tourism Benefits to Communities.

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SUMMARY: *In 1990 the railway line in to Central Otago was closed as the completion of the Clyde Dam (Think Big) project was reached. At the same time the need to retain the former Otago Central Railway line between Middlemarch and Clyde was being discussed, recreationists and others were promoting an overseas concept known as Rail Trails. Owen Graham was involved in the earliest investigations into the conversion of the railway line into a walking and cycling trail and worked on the Otago Central Rail Trail project from 1993 through to 2006. Between 1994 and February 2000 when the Otago Central Rail Trail was officially opened along its full 152km length, the Department of Conservation (DOC), with support from the Otago Central Rail Trail Trust, redeveloped the former railway corridor for use by walkers and mountain bikers. The 68 bridges, several over 100m in length, needed engineering checks and design modifications before they were re-decked, with handrails added for safety, and most of the 150km had to be re-surfaced to accommodate the new users on foot and by pedal power. Notably, the Rail Trail project not only created a new and much needed recreational facility, but it preserved most of the historic and heritage values of the former branch railway and has encouraged an appreciation of the heritage past in communities along the route. The Rail Trail is a unique recreational facility and provides a prime opportunity to appreciate a special part of New Zealand's railway heritage, first hand. As well, the Rail Trail has become an important tourism attraction for Central Otago. All who ride or walk the Otago Central Rail Trail take away something different to treasure in their memories, be it discovering a tough and adventurous Otago history, marvelling at the engineering feats of those early pioneers or the wild, natural surroundings, then finding out they could bike further than they ever guessed, perhaps beating the challenge of a dusty head wind.*

Figure 1. *The impressive Poolburn Viaduct dates from 1901 and shows the detailed stone work and major engineering involved.*

Figure 2. *The bridge over the Taieri River near Waipiata illustrates one of the many engineering styles used on the Otago Central branch line.*

1. INTRODUCTION

I love the Otago Central Rail Trail and so to, it seems, do tens of thousands of other people in New Zealand and from overseas. I worked on the Rail Trail project from 1993 until 2006 when the success of the venture was finally being realised nationwide. As we now know, the Otago Central Rail Trail is a shining example of how a defunct infrastructure asset can be recycled for new uses that will benefit communities not only economically but also in a far broader social sense.

The New Zealand Rail Trail is now a possibility as central government commits resources to investigate and provide a network of similar Rail Trails. That support was not always present during the formative years of the Otago Central Rail Trail, both at central and local government levels.

During my 13 years as project manager I was able to guide the project and see it develop and succeed both in terms of the reconstruction of the bridges and infrastructure to support users, and in the way communities became 'captured' by the possibilities it meant for them and their own survival. From quite desperate times in the early 1990's the many small communities along the line today blossom and prosper as tourism dollars from national and international visitors cycle their way through the Central Otago heartland.

First, a little history. Originally the Otago Central Railway was constructed to transport gold out from the booming Central Otago goldfields of the late 1800's and into the bustling Dunedin City. Otago was once the hub of New Zealand's economy. The discovery of payable gold in 1861 brought a rapid influx of miners and entrepreneurs, farmers and families. Towns were built along with roads and finally a railway. In the days before the railway it could take two days by coach from Dunedin to reach the Central Otago towns of Alexandra and Clyde.

Construction of the Otago Central Railway began on 7 June 1879 at Wingatui near Dunedin. Progress was slow as the first 64km followed the Taieri River through the Taieri Gorge to the Maniototo Plain, requiring numerous bridges, cuttings, and ten tunnels. It wasn't until January 1891 that the line reached Middlemarch (today an hours drive from Dunedin). The remaining 152km of line then pushed through the Ida and Manuherikia Valleys of Central Otago to Alexandra and on to Clyde by April 1907. Between 1914 and 1921 the line was extended to Cromwell.

The railway was created in a clamour of picks, shovels, hammers, horse and wagon teams, dynamite explosions and the shouts of working men. The skills of masons, carpenters and blacksmiths were constantly in use, not least in the bridges and viaducts whose wooden and metal sections were winched down or jacked up into place. All of the stone work along the line was done by hand. As far as we know the builders were Polish, German and Italian stone masons who reverted to their old trades after the easily won gold in Central Otago ran out.

By the time the railway was completed, the gold rushes for which it had been intended were well over and the railway did service instead transporting farming produce and fruit from orchards, as well as passengers to Dunedin. In the forty years it took to complete the railway, over 60 bridges and three tunnels were built on the Rail Trail section between Middlemarch and Clyde. They provide a chronological and technological record of bridge types, running from typically Victorian stone work to American trestle bridges to 'modern' concrete.

Figure 3. *Stonemasons at work cutting stone for another Otago Central Railway bridge - Hocken Library*

Figure 4. *Workmen in front of one of the tunnels on the Otago Central Railway - Hocken Library.*

Figure 5. *Workers laying tracks on the Otago Central Railway - Hocken Library.*

I have entitled this presentation very deliberately **'Preservation of Heritage Sites through Development for Visitor and Tourism Use: A Case Study of the Visitor and Tourism Benefits to Communities'**.

In this one project, it has been possible to:

- **Preserve, restore and maintain what has been described as one of the best remaining examples in New Zealand of a late Victorian railway system**

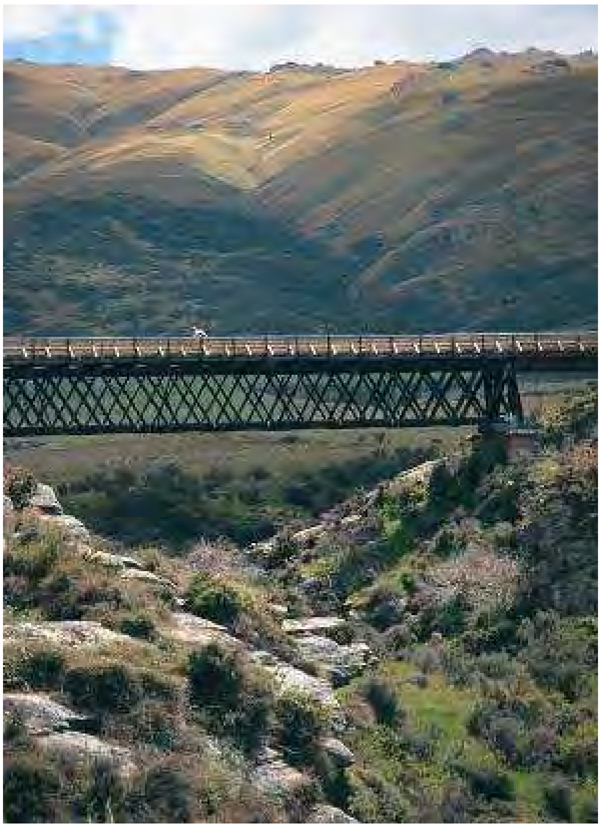

Figure 6. *Five Mile Creek Bridge.*

- **Develop a multi-purpose recreational facility 'often referred to as the 'Routeburn Track of Central Otago' and**

Figure 7. *Bikes on Muttontown Viaduct in Autumn - Gilbert van Reenen.*

- **Create a tourism product that can be directly attributed with facilitating the rejuvenation of the many small Central Otago towns along the Rail Trail.**

Through the 1990's, rural towns in New Zealand lost many of their services and suffered from reducing population as banks and post offices closed and many businesses moved away. In Central Otago the same pattern followed including the closure of the branch railway line affecting 10 towns and communities that had once been formed because of the railway, and had in latter years relied on it. In 1993, after the closed railway had been stripped bare of tracks, sleepers and its old station buildings, the abandoned land was taken over by the Department of Conservation (DOC). Based on the U.S. Rails to Trails concept, DOC set out to convert the 150km railway corridor in to New Zealand's first Rail Trail for mountain biking, walking and horse riding.

At the time, the then Minister of Conservation, Denis Marshall said, “Intact, the railway corridor is potentially a unique asset. It will take walkers and cyclists through the striking Central Otago landscapes away from roads and traffic. There is nothing quite like it in New Zealand and it could well become a tourist attraction of considerable international interest”.

DOC today manages the Rail Trail as a public recreation reserve but it is also an important heritage site preserving as it does, the route and the engineering achievements of those early pioneers. To understand this best requires some understanding of the engineering accomplishments now retained and preserved along the Otago Central Rail Trail. There are a few examples which highlight this.

2. BRIDGES

2.1 Capburn Bridge

Bridge 56 on the Otago Central Railway line was the Capburn (completed 1897), a large masonry and lattice truss bridge. The trusses are wrought iron, and the only basic modification to the bridge is the replacement of the timber sill and corbels on the southern most pier with pre-cast concrete in 1937. The masonry work is basalt, some of it quite brown rather than blue/black and nicely brought to course with lightly bolstered faces. They may be the largest brought to course basalt structures in Otago, and are the largest masonry piers on this section of the line. The presence of basalt nearby at Kokonga may have influenced its use, as basalt is stronger under shear than schist.

Figure 8. *The Capburn Bridge at Tiroiti showing fine stone work abutments and lattice sub structure.*

2.2 Waipiata Bridge

Completed in 1898 and extensively repaired in 1931, it is a four span steel truss bridge with three sets of wrought iron cylinder piers filled with concrete. The Bridge was designed as a road/rail bridge though no road ever ran to it. The high sided steel truss system makes this Bridge No. 59 unique among the 68 bridges along the Rail Trail.

Figure 9. *Waipiata Bridge being re-decked for cyclists and walkers.*

2.3 Poolburn Viaduct

The highest bridge on the line (No. 69, completed in 1901) is also the one with the longest span (47.5m for one of the centre spans). It is the second longest bridge on the Rail Trail (108m) and represents the last of the big masonry pier bridges (with steel trusses) built on the line. Even in 1901 it was something of an anomaly. Subsequent bridges on the line were completed post 1901. The abutments, 36.8m high, are made of beautifully trimmed and bolstered stone, all brought perfectly to course. During construction large gantry hoists were used to lift and position the stone slabs. Holes on the stone piers show where these hoists were fitted during construction. All the stone was locally quarried from outcrops close by.

Figure 10. *Poolburn Viaduct with Dunstan Mountains beyond.*

2.4 Manuherikia No.1 Bridge

Bridge No. 70 (completed 1903) is the longest bridge on the Rail Trail at 110.6m and is the first of the true concrete pier bridges. The foundations here were built by sinking caissons into the river bed. These were filled with compressed air for the men to work in. When the caissons were sunk far enough, the men were taken out and the concrete fill poured in. The piers were built with a taper. The bridge is one of only two curved bridges on the whole 150km Rail Trail, the other being the Hyde township bridge.

Figure 11. *Manuherikia No. 1 bridge was the first built using concrete for the piers.*

2.5 Muttontown Viaduct

This is the only bridge on the 8km section of Rail Trail between Clyde and Alexandra. Bridge No. 86 (completed 1906) is the longest trestle bridge on the Rail Trail but like most of the trestle bridges on the line, its hardwood beams have been replaced with RSJ's.

Figure 12. *Muttontown Viaduct near Clyde showing raker bracing.*

2.6 Prices Creek viaduct

The present Prices Creek bridge (90m long) named for an early gold miner, was built between 1961-63 on a line deviation to replace the unstable (1896) wooden structure located upstream on slumping ground. It is the youngest bridge on the line and comprises six spans on reinforced concrete piers with concrete abutments. Each of the spans are made of steel plate girders (No.'s 1, 2, & 3 riveted). The bridge stands 28.9m above the creek.

Figure 13. *Prices Creek viaduct near Hyde, built in early 1960's it was the last bridge built on the line.*

3. TUNNELS

3.1 Poolburn Gorge tunnels

Two tunnels located in the Poolburn Gorge (No.'s 1 & 2) are both constructed of bolstered schist slab facings on the portals with the arches outlined in brick, at variance to the many arched culverts on the line outlined with schist. The interior of both tunnels is simple brick arch for a distance of 10m then bare rock.

Figure 14. *Poolburn Gorge tunnel.*

4. VISITOR AND TOURISM BENEFITS

The significance to the local communities of retaining the Rail Trail is directly related to the range of benefits which are now being gained from preserving and protecting those remaining structures and formation of the old railway system.

Research by DOC and the Rail Trail Trust since 2001 has confirmed a variety of benefits to communities and users of the Rail Trail including:

- economic,
- social
- heritage appreciation
- personal

5. HERITAGE BENEFITS

The economic benefits are now widely known and there has been a total rejuvenation of the small townships along the Rail Trail. Another benefit has been the recycling of income into community enhancement projects, restoring and upgrading civic areas once left neglected.

This enhanced understanding that the preservation of local heritage reflects the meaning that some local people attach to the Rail Trail in connection with local area history and the value that the Rail Trail has as a component of a 'special place'. The Rail Trail brings new people in to the community who are fascinated with the landscape, the rural identity of the towns and the people. This has all given a renewed sense of community identity and pride. Results from respondents are representative of how many locals think about the area which the Otago Central Rail Trail passes through.

"It is important that our heritage is preserved and perhaps even more now that other people can see it and experience it… The historical value of the trail is very important. Poolburn viaduct and Poolburn tunnels; I mean to have made those over 100 years ago just shows you the engineering feats that could be done with a pick and shovel"

"It has enhanced the communities' perspective of the history around this area as well. Our sense of place. That's why I feel strongly that you could so easily spoil it. Its something that is very precious…that's got to be positive"

"There's the link in with the early settlers that you get from the great information boards that DOC and the rail trail trust have put in which gives you that theme back into that little community and why its there and what its about and things like that. It's more than just recreation for me and I suspect for a lot of other people as well".

"Reliving memories, an appreciation of what has been done to preserve an important part of this areas heritage - fantastic job and it is open to everybody - anybody of any level can do it; can see what's here. We have all gained something because the railway in a way hasn't been lost"

"There is no doubt it's preserved the railway in some way. What would they have done with the Poolburn viaduct if they didn't use it for a tourist attraction – what would have happened to it. It would have just sat there. I suppose they could've scrapped it for the steel. But, it would have been terrible to pull it down. It would be like taking a part of our heritage away. It preserves our heritage in a way. The only reason Ranfurly is here is because of the railway line".

6. CONCLUSION

The Otago Central Rail Trail project has proven that preservation of heritage can be a catalyst for economic rejuvenation, provide a source of pride to the community and help to tell the early pioneering stories that have shaped this country. It is through the combination of heritage retention, economic incentive and growing recreational needs that the Otago Central Rail Trail has been so successful.

The Rail Trail has been described by the Tourism Dunedin CEO as, 'the best example of social and economic recovery, through Tourism, in New Zealand. It has revitalised small towns in a remote part of the country'. The CEO of Tourism New Zealand has stated that the Rail Trail is 'exactly what active tourists or independent travellers want to experience. It allows people to experience the landscape, and have a quality experience.'

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Early Water Races in Central Otago

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SUMMARY: *Gold mining was the driver for the first water races constructed in Central Otago from the 1860s. As the easy gold was won and the races abandoned by the miners they were used for domestic and stock water and then irrigation of pasture and horticulture. Many of the races are long, on steep hillsides, and construction was undertaken with limited resources. These races continue to be used although a number have been upgraded to allow vehicle and machinery access. The paper presents two case studies: the 108 km Mt Ida Water Race constructed from 1873 to supply water to the Naseby gold mining area that still supplies water to Naseby township and farmers in the area; and the Teviot irrigation and hydro-electric power system near Roxburgh that was developed into the combined system after a goldmining venture failed in 1922. Both networks and water rights became owned by the Government. The Public Works Department carried out modifications and extensions for distributing water to both systems in the 1920s. The Mt Ida Water Race starts at 850m altitude and collects water from numerous small mountain catchments along the Hawkdun and Ida Ranges. The Teviot system relies on the Teviot River and a 13m high 46Mm^3 storage dam at Lake Onslow at 680m altitude and utilises some 370m of fall. The systems are now owned and operated by companies. The paper also introduces the principal irrigation dams in Central Otago in summary form. It concludes that the water supply systems originally built with their focus solely on gold mining have been successfully transformed into multipurpose water supply systems for irrigation, domestic, stockwater and hydropower.*

1. GENERAL

Gold mining was the driver for the first water races constructed in Central Otago from the 1860s. As the easy gold was won and the races abandoned by the miners they were used for domestic and stock water and then irrigation of pasture and horticulture. Many of the races are long, on steep hillsides, and construction was undertaken with limited resources. Two case studies are presented, the Mt Ida Race and the Teviot system. In addition older community irrigation dams in Central Otago are introduced.

2. MT IDA WATER RACE

2.1 Mining and construction

Alluvial gold mining began in Naseby in 1863 (Hamel), using water from the Hogburn and a number of other races from the East Eweburn and the Kyeburn. The disposal of tailings was difficult, because of the lack of flushing water and the relatively flat grade from the mining area out to the Maniototo plain. It was considered that two to three times as much water as was available in 1871 would be required and that the Manuherikia would provide the most reliable supply, although expensive. Figure 1 shows the nature of the catchment area. Estimated cost was $20,000 for the construction of this water race. The primary purpose was to flush accumulated and future tailings down the new sludge channel.

The race was designed and supervised by Mr DL Simpson, the Otago Provincial Engineer. He also designed the 16km long sludge channel down the Hogburn.

The Mt Ida Race works were authorised by Governor's Proclamation on 17 October 1873, and the route of the race and the streams reserved for its supply are identical with present day usage. The race was opened on 26 July 1877.

Figure 1. *Water supply catchment*

The Mt Ida Race sidles the Hawkdun Range from the tributaries of the Manuherikia River for 108km to

Naseby (see map in Appendix A). The start is at about 850 m above sea level and delivers water at 634m at Naseby. There is a drop of about 50m over 1.5km through use of a gully at Kirkwoods Creek. Water is diverted and taken from most streams the race crosses.

The original race dimensions were 1.2m bottom width, 2.1 m top width and 0.9m deep on a grade of 1 in 754.

By 1881 there was a permanent waterman with hack for inspection work and a draught horse and dray for cartage, plus five men stationed along the race, each looking after about 22 km. Extra hands were employed after slips and after the winter closure of two to three months.

Storage for the system is limited and consists of the West Eweburn reservoir (2.4 million m^3) which is 87 km from the start of the Mt Ida Race, and one smaller reservoir (Paisley's (Hore's) Dam) at the termination of the race in Home Gully near Naseby. Over the period 1898/99 to 1901/02 this 21m high earth dam was built immediately above the race in the West Eweburn (see Figure 2) to provide supplementary supplies to the Naseby area particularly in late summer.

Figure 2. *West Eweburn Dam construction 1898?*

Water for mining was supplied under agreement with the Mines Department at $0.20 per 1000$m^3$ (1 Ml) and the income from the sales was intended to provide a profit over the operation and maintenance costs. The race initially supplied about 135 miners but by 1900 there were 65 miners using the water and by 1918 about 25-30 miners.

A plot of available water by section derived from Mines Department 1922 data is still considered to give a reasonable assessment of the potential supply from the 3 sections (described below) in a "normal" year. See Figure 3.

2.2 Irrigation Development

By 1920 the value of mining had fallen off, both the Blackstone Hill race and the upper part of the Mt Ida race having been abandoned, the latter since a storm in 1918 washed out many of the stream crossings. At this stage the Mines Department made the suggestion that the scheme be taken over for irrigation and/or power by the Public Works Department, but made the condition

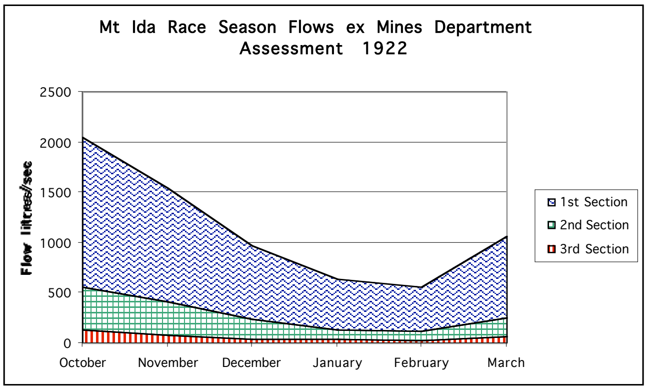

Figure 3. *Seasonal flows by race section*

that mining water should still be supplied. At this stage the mining system was running at an annual loss approaching $1,400.

There is very little stream flow in these areas and some farms were without adequate water for stock.

Initial reports on the taking over of the scheme were not very favourable due mainly to the taking of water from the Manuherikia watershed, where it was required for other irrigation schemes. A proposal for using the Eweburn reservoir for hydro-power was mentioned but not carried further. However, following a certain amount of pressure from the farmers of the area, and a decision to provide a storage dam in the Manuherikia River, recommendations were made in early 1922 that the scheme be taken over for irrigation. At a meeting in January 1922, it was made clear to the farmers that only partial irrigation and stockwater would be available.

An estimated cost of reconstruction of the system, and new construction, was provided in mid-1924 with a figure of $40,000 to be covered by a charge of $1.85 per hectare over 4,000 hectares. A further delay was caused by difficulties with the miner's agreements, requiring additional clauses giving PWD the right to cut off mining supplies between 1 January and the end of March, and removing the requirement that miners maintain the system. The existing scheme and 2 officers of the Mines Department were transferred at the beginning of September 1924.

Owing to the widespread demand for water for irrigation and stock, and the relatively small supply of water available in summer, there was a choice between full irrigation for a few, and some water for the whole area. The latter course was decided upon and the Hawkdun is considered only a partial irrigation scheme and it was put to the farmers and accepted on that basis.

Before money was provided for construction it was necessary for farmers to sign a petition with the area they proposed to irrigate, the final list of June 1925 giving 3,954 hectares with 65 signatures. The signing of agreements followed this, 68 with an area of 3,102 ha being signed by the end of January 1926. This was not the final figure but provided the 50% required by the Act, there being 126 irrigators within a total scheme area commanded of 30,920 ha.

The area was proclaimed an Irrigation District by an Order in Council of 8 April 1926, the full re-estimate at this stage giving cost as $118,000 (including $38,000 towards the cost of Falls Dam on the Manuherikia River), and the area charge of $2.60/ha allowed for agreements being automatically approved. Construction work was started almost immediately but not completed until mid-1929, and then at a cost of over $120,000. Supplies were commenced in 1929/30 season.

It was realised from the beginning that water supplies to the two areas would not be plentiful and experience has shown worse conditions than anticipated. At the original meeting of Hawkdun settlers on 5 December 1924, Mr Lindup of the PWD gave figures of 0.35 l/s/ha as average supply but falling to 0.21 l/s/ha in January and February. Agreements were to allow for the 0.35 l/s/ha (457mm per season) over an area of 4,047 ha. A slightly higher figure was allowed for supply to the Idaburn area.

The Mt Ida race was enlarged, as part of the reconstruction work, to carry 1.41 m^3/s as far as the Idaburn and 0.71 m^3/s from there to Naseby. A mean flow of 1.19 m^3/s was allowed for a minimum, with Eweburn dam being drawn down, of 0.85m^3/s.

Through the 1930's the main complaints about lack of water came from the miners. Despite the maintaining of supply at the $0.20 per 1000$m^3$, a considerably lesser return from the gold won led to the cancelling of the miners' agreements in 1938.

Figure 4. *Ten Chain Creek Bywash and control on Mt Ida Race in top section*

2.3 *Description of Sections*

First Section Mt Ida Race

The first or top section of the race runs 49 km from the head of the Manuherikia Valley to a gauging weir on the Manuherikia-Idaburn divide, and is solely a supply race picking up water from the streams it crosses. The top intake is at 850m above sea level. The race sidles high on the western slopes of the Hawkdun Range crossing into easier country of the Idaburn catchment below Johnstones Creek. Streams crossed by the race and able to provide water are:

- Johnstons or Head Creek or Top Johnstons Creek
- Manuka Creek
- Big German Creek
- Boundary or Kirkwoods Creek
- Big Bremners Creek
- Shepherds Hut Creek
- Healeys Creek
- Hut Creek
- Pierces Gorge Creek
- Johnstones Creek

In addition small quantities are picked up from Little German, Little Bremners, Trinity and Gate Creeks but as these effectively dry up when water is most needed late in the season they are not considered separately.

A number of these creeks traverse steep alluvial fans before reaching the Upper Manuherikia River. Under normal to low flow conditions many of these streams across the fans naturally dry up through infiltration in the gravel bed. The siting of the Mt Ida Race to be able to pick up creeks at a point where they have flow would no doubt have been a consideration of those involved with the original race construction.

By its nature this section of the race is very subject to washout, particularly at stream crossings, and maintenance and repair may be difficult and costly. Maintenance work is required in the streambeds from time to time, primarily after freshes or floods.

Mt Ida Race Second Section (49 to 76.6 km)

This section runs from the above section to a weir at the catchment boundary between the Idaburn (Clutha) and the Wetherburn (Taieri). Various streams are crossed by the race and picked up, including:

- Hills Creek (see Figure 5)
- Wades Creek
- North Idaburn
- Idaburn

Irrigation and stockwater is distributed to farms in the Idaburn valley through a mix of natural watercourses and distributary races.

Figure 5. *Hills Creek intake*

Mt Ida Race Third Section (76.6 to 108 km)
This section runs from the Taieri catchment boundary through to Home Gully, and follows the base of the southern slopes of the Mt Ida Range.

Figure 6. *Mt Ida Water Race west of Gorge Creek*

The race passes through the Naseby forestry (see Figure 8) and old mining areas to finish at an altitude of about 634m. Major streams crossed are:

- Wetherburn (main race does not pick up water as deeply incised channel) – see Figure 7
- West Eweburn (below main water storage reservoir)
- Butchers Gully (unreliable)
- East Eweburn (unreliable)

Figure 7. *Wetherburn syphon sluice valve in operation*

Figure 8. *Mt Ida Race adjacent to Naseby reservoir*

2.4 Current operation

In the 1980s the race was made more accessible by vehicle and hydraulic excavator over most of its length by widening the downhill berm.

The Mt Ida Water Race is today owned and operated by the Hawkdun Idaburn Irrigation Company Limited that is owned by the farmer shareholders with 3530 hectares under agreement for irrigation supplies. The race supplies domestic water for Naseby, back up supply for the township of Ranfurly, water supply for the curling and ice skating rinks, firefighting supplies for the forestry area and stockwater to the 30,000 ha commanded.

3. TEVIOT IRRIGATION AND HYDROPOWER DEVELOPMENT

3.1 Mining and Construction

Water race construction in the Teviot area was initiated by miners in the 1860s after gold was discovered in the Teviot River in 1862. Water was used for sluicing and hydraulic elevating. Mining water rights out of the Teviot River were held by the Roxburgh Amalgamated Mining & Sluicing Co. In 1888 Vincent Pyke gained a dam licence that he sold to the Company. Mr C C Rawlins (general manager of the Island Block Mining Co) designed a 5.5m high stone course dam, including the base set 0.9 to 1.2m into solid rock) in the same year at Dismal Swamp, now called Lake Onslow (see Figure 9). Lake Onslow is named after a governor of New Zealand, William Hellier, fourth Earl of Onslow, 1889-92. A further 1.52m was added to the dam in 1894 by Mr H M Davey, consulting engineer, of Dunedin (see Figure 10).

Lake Onslow is about 30km from the confluence of the Teviot River with the Clutha River and 600m higher in elevation. About 220m fall is available over the last 3.6km. Mean annual flow of the Teviot River is 2.3 m^3/s. See map in Appendix B.

In 1897 T Perham A.M.I.C.E. was employed by the Mines Department to report on various water conservation schemes on goldfields. He prepared a plan for a further raising of the dam by 3m but considered that this would only benefit existing holders of water rights and he could not recommend government involvement as he was charged with finding water for new ventures. This addition was not carried out. See Figure 10.

Figure 9. *Lake Onslow Rock Dam after 1894*

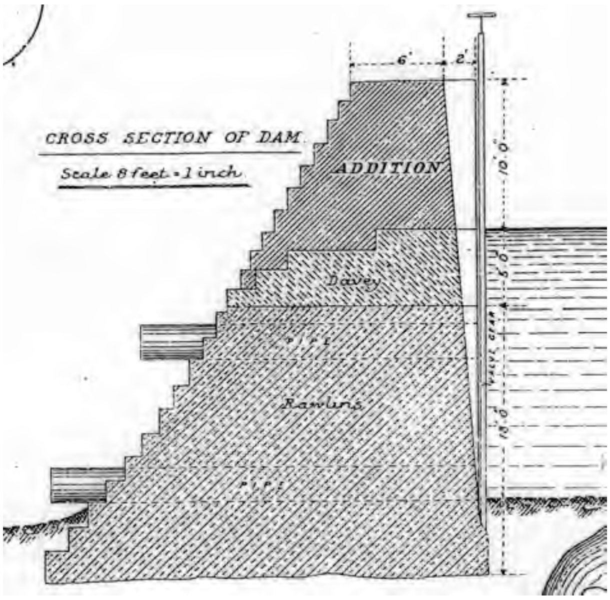

Figure 10. *Cross section of Lake Onslow Dam with T Perham possible addition shown*

The last large undertaking in gold mining was the Teviot-Molyneux Gold Mining Co.Ltd whose managing director was John R Ewing (Figure 11). Ewings race construction involved a tunnel, 2 km of 900 mm iron pipes taking water from the Teviot River gorge and 8 syphons. The race was over 200m above the Clutha River level and thus provided good pressure for sluicing and hydraulic elevating for gold mining (see Figure 14). The race capacity in 1971 was 500 l/s and total length of 6.9 km. Figures 12 and 13 show examples of the race features.

Pipes were manufactured locally. See Figure 15.

Figure 11. *John Ewing (front) on site*

Figure 12.*. Ewings Race at 2550m (1971)*

Figure 13. *Ewings Race Syphon No.3 (1971) 590mm diameter steel, 314m long*

Figure 14. *Sluicing and elevating at Roxburgh East using water from Ewings Race*

Figure 15. *Steel pipe at Roxburgh Foundry*

3.2 Irrigation and Hydropower Developments

In January 1920 three local landowners were discussing the current dry spell and a suggestion was made that they could divert the Teviot River through a tunnel and irrigate Roxburgh East. Mr R George was one of these three men and as Chairman offered the Ladysmith Gold Dredging Co water rights and plant as suitable to supply Roxburgh with electric power as that company was nearing liquidation. Thus was spawned the idea of a combined irrigation and power system. Two days after the initial discussion a public meeting was held with 70 attendees. A Mr CJ Drewett from AD Riley & Co. happened to be in the area and had been able to prepare a preliminary design and costings and estimates of revenue that day. A committee was formed to lodge tenders for the Ladysmith claim and plant. The committee adopted the name of the Teviot District Electric Lighting, Power and Irrigation Board and jointly guaranteed the sum of $6,000 to progress the matter. Within a few days they had tendered for and purchased the plant and water rights of the Ladysmith Co. for $3,020.

In 1920 the Roxburgh Amalgamated Company had folded disposing of its plant and water rights for $2,500 to the newly formed Teviot Electric Power Board (TEPB) that had been constituted as an electric power board district on 16 July 1920.

As at February 1921 there were three holders of water rights from the Teviot River:

Roxburgh Amalgamated Co (TEPB)	780 l/s
Ladysmith Company (TEPB)	850 l/s
Teviot-Molyneux Co.	1,175 l/s
Total	2,805 l/s

One of the first actions of the Board was to appoint an engineer, Mr A P Aldridge, who at the time was an engineer at the Dunedin City Council Waipori Falls Power Station.

The Board's early estimates of revenue were based on three 60W lights and one hot point per dwelling at $8 per annum or six 60W lights and one hot point for $12 per annum.

John Ewing died in 1922 and his company went into liquidation, the water rights being taken over with many of its assets by the Mines Department as mortgagee.

The Resident Engineer for the Public Works Department (PWD) at Alexandra, J R Marks, suggested taking 2.1 m^3/s from the Teviot R to irrigate 5,340 hectares on both sides of the Clutha R with two power drops to produce 950 kW. In 1922 Government approved the TEPB selling water for irrigation at $4 per hectare. A revised irrigation proposal to utilise existing races and water from the tailwater of the proposed power development was put to a meeting of settlers, TEPB and PWD in November 1922 and owners of land agreed to sign up 1,092 ha for irrigation water at this price.

Mr Aldridge had prepared the original scheme for the TEPB and was also involved with formulating the new proposals including irrigation. The level of the power station was set to allow for gravity supply of irrigation water to the north side of the Teviot River. See Figure 16 showing the relative levels of the races and powerhouse in diagrammatic form. Delay in commencement of supply was involved as reordering of turbines and generators and cancelling of existing orders was required. The first power pole was erected on 12 February 1923.

In January 1923 construction was approved at an estimated cost of $43,082. Proposals were altered in July 1923 when second hand pipes could not be obtained. An agreement as to site work responsibilities and cost sharing between the PWD and TEPB resulted in the TEPB surrendering all mining privileges and rights to sell irrigation water in return for the Crown maintaining all works apart from the powerhouse and electrical fittings, lines and poles.

The Teviot Irrigation District was gazetted on 5 July 1923 authorising the Minister of Public Works to construct and maintain water supply works in the District. A legal agreement between His Majesty the

King and the TEPB is dated 27 September 1924. A minimum of 708 l/s was to be supplied to the powerhouse. The first irrigation water officially supplied under the scheme was on 1 September 1924.

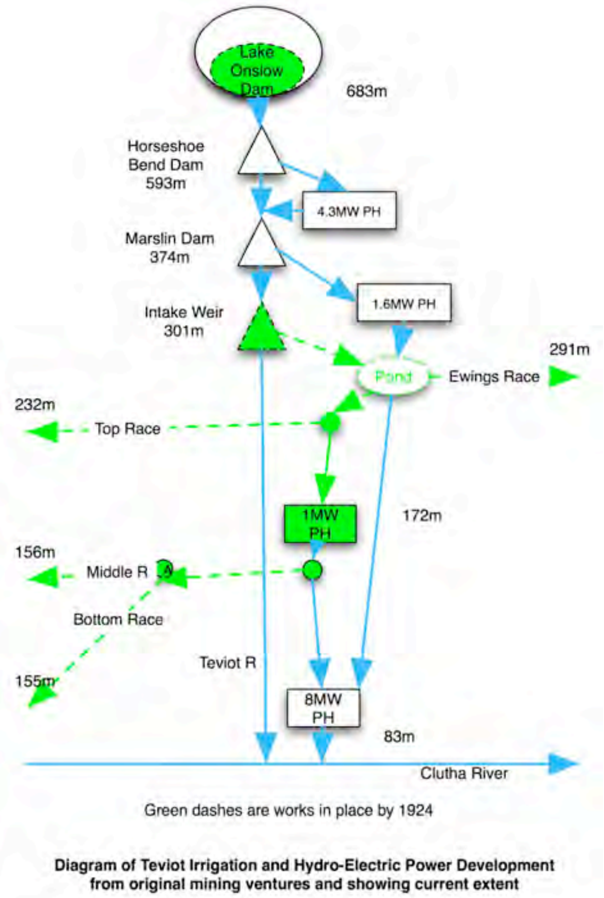

Figure 16. *Diagram of Teviot system*

The first power was officially turned on at a ceremony on 27 March 1924. Generation and distribution was at 3,300V. By November 1924 there were 321 consumers connected. Figure 17 shows the original powerhouse in operation.

An extension towards Millers Flat was mooted in 1927 and construction finished in 1929 serving an additional 490 ha under agreement.

In 1930 proposals to increase power were suggested. Also 1.77 km of 900mm pipe was to be replaced and the option of a 1.55 km tunnel to provide relief work and thus be subsidised by the Unemployment Board was taken with a concrete lined tunnel 1.45m x 1.12m finished size was in service by October 1935. Design capacity 2,830 l/s with mean velocity 2.35 m/s.

After a dry season in 1932/33 the TEPB suggested raising the dam by 900mm to increase storage by 3.45 Mm^3. This was accomplished in 1933 at the estimated cost of $600 using angle iron frames bolted to the top of the existing dam with 75mm hardwood sheathing. Following another dry spell in 1937 an additional 225mm raising was carried out in May 1938 at an estimated cost of $100 for 0.94 Mm^3 of storage capacity.

Figure 17. *Original Teviot (George) power station*

In an April 1968 flood 28m of the timber and steel superstructure and 15m of masonry capping 0.6m deep was carried away, effectively reducing storage capacity by 60%. See Figure 18. Options to further increase storage based on the existing dam structure were ruled out with dam stability issues and the dam was reinstated to its level prior to the flood using a concrete cap. See Figure 19.

Figure 18. *Lake Onslow Dam 1968 flood damage and showing masonry construction*

***Figure 19.** Lake Onslow Dam 1971*

The masonry quarried on site had a density of 2.515 t/m^3. Representative rock size used was 1.2 x 0.6 x 0.45m.

3.3 Recent changes

The Otago Central Electric Power Board (including the Teviot EPB generation and network) sought new development to build a new dam at Lake Onslow 14.6m high to store 46 Mm^3, and additional generation stations. This would require a new agreement as to cost sharing and responsibilities. The power generation system is now operated by Pioneer Generation Limited and the irrigation by the Teviot Irrigation Company Limited.

The new Lake Onslow Dam was completed in 1982 and the original dam is now submerged.

The high head available through the irrigation and power pipelines have been useful for gravity frost fighting of orchards at Roxburgh East. Capacity is however limited as the frost demand is by all orchards at once whilst irrigation supplies can be rostered over 2 to 3 weeks.

4. IRRIGATION DAMS

Apart from the two dams described under the Mt Ida and Teviot systems above there were no major dams for mining purposes and miners relied on picking up stream runoff and conveying the water many kilometres to their claims.

A number of good storage sites exist in Central Otago with narrow schist gorges and relatively wide flat basins above. Some of these sites are in relatively low rainfall zones with annual rainfall variability of ±30% about the mean. Storage at some sites is thus based on the ability to store water over years rather than just winter-spring runoff for the next summer-autumn. In order to improve reliability of supply old mining races have been used to add catchment area in some cases.

From 1914 to 1937 the Public Works Department constructed a number of purpose built irrigation dams. These are predominantly thin curved concrete arch dams with overflow spillways. Appendix C table summarises these irrigation dams and also includes the earlier two mining related dams and the Loganburn Dam completed in 1984.

Figure 20 shows Falls dam under construction (rockfill with concrete membrane) and Figures 21 and 22 show Conroys Dam as an example of the thin curved concrete arch dams.

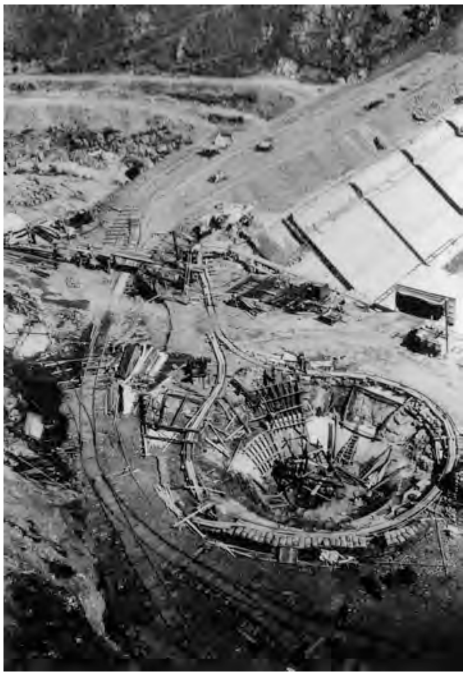

***Figure 20.** Falls Dam under construction 1934 showing morning glory spillway in foreground*

These dams could provide sufficient material for papers on their own so this is only an introduction for engineering heritage record purposes.

***Figure 21.** Conroys Dam 2006*

***Figure 22**. Conroys Dam from right bank*

5. CONCLUSIONS

The early construction of water races for the purposes of gold mining were undertaken at a great pace and are remarkable for the engineering at the time. The Public Works Department was able to coordinate the development of community irrigation and assist hydro power development through acquisition of the mining water rights and assets as mining became less profitable in the 1920s. The ongoing use of the water distribution systems, originally built with their focus solely on gold mining, have been successfully transformed into multipurpose water supply systems for irrigation, domestic use, stockwater and hydropower.

6. ACKNOWLEDGMENTS

Assistance from the Naseby Museum and Teviot Museum is acknowledged for access to photographs. Access to information from Last Chance Irrigation Co Ltd, Hawkdun Idaburn Irrigation Co Ltd, Pioneer Generation Ltd and the Ministry of Agriculture and Forestry has been appreciated.

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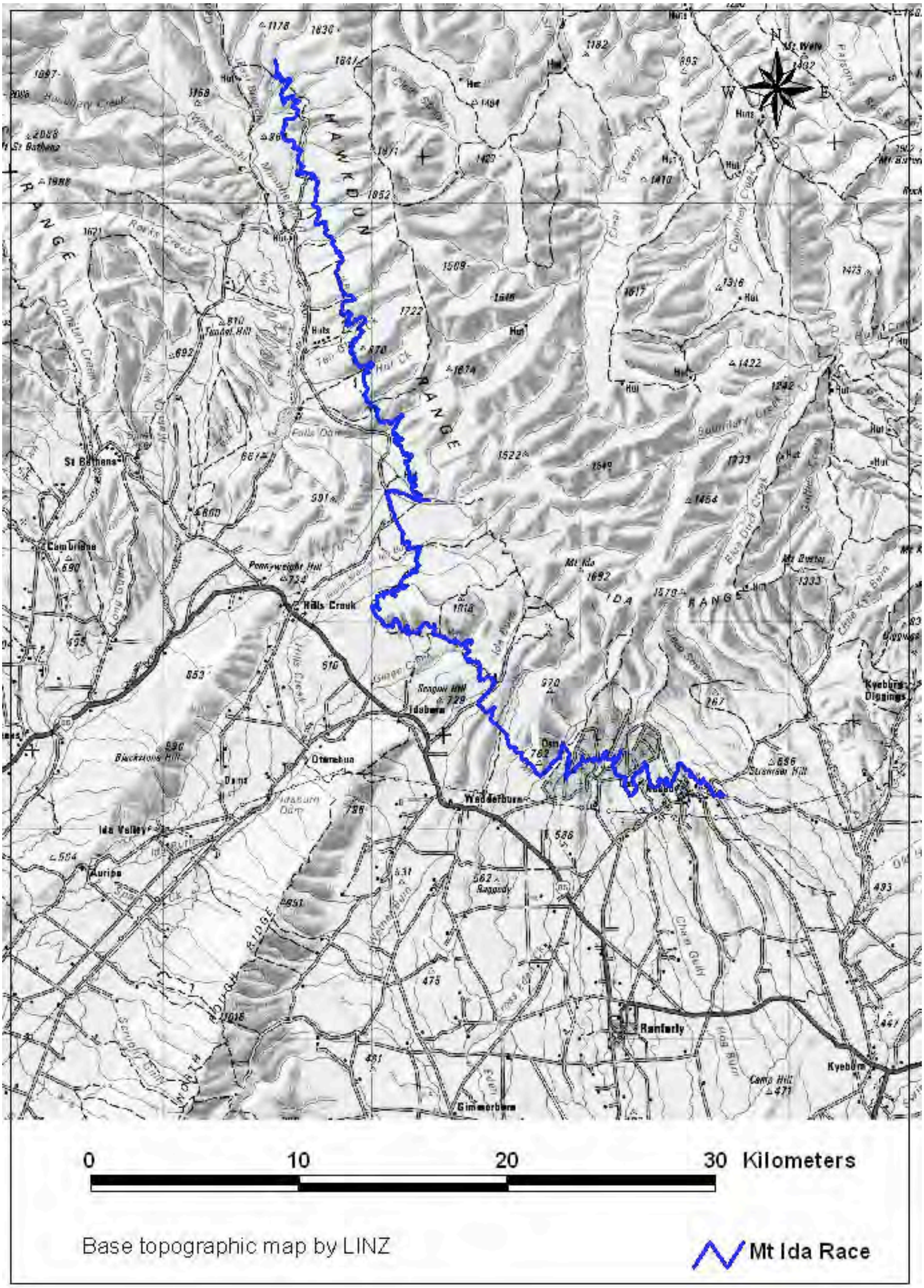
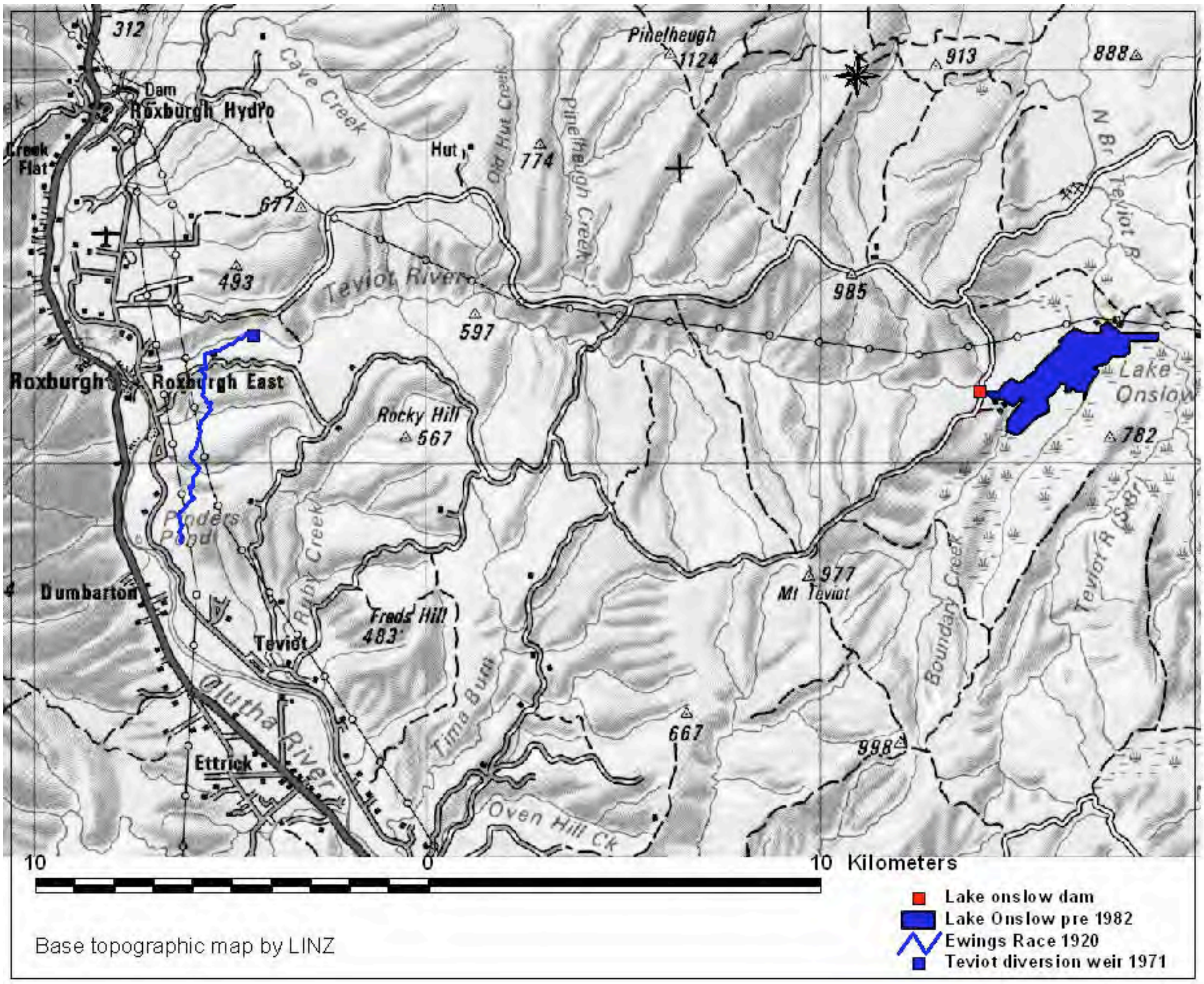
8. APPENDICES

Appendix A – Location map Mt Ida Water Race
Appendix B – Location map Teviot Lake Onslow and Ewings Race
Appendix C – Table 1 – Central Otago Irrigation Dams

Appendix A – Location map for Mt Ida Water Race



Appendix B – Location map for Teviot Irrigation and Power



Appendix C – Table of Central Otago Irrigation Dams

Dam	Date Completed	Brief description	Basic dimensions		Reservoir Volume (10^6 m^3)	Catchment Area (km^2)
			Height (m)	Length (m)		
Lake Onslow	1888	Stone course gravity dam	5.5			
	1894	Increased height	7.0			
	1934	Steel frame hardwood sheath addition	7.9			
	1938	Additional height	8.13		10.16	
	1968	Flood damage reinstatement concrete cap + timber/steel frame	8.13	50	10.16	175
	1982	Concrete arch downstream of original now drowned	12.8	-	46.5	
Eweburn	1902	Earth embankment with clay u/s & rockfill d/s layers	21.3	189	1.65	14
Upper Manorburn	1914	Concrete arch with mass concrete right abutment	27	123.6	50.9	90
Poolburn	1931	Concrete arch with mass concrete right abutment	32.8	163	28	53
Idaburn	1931	Concrete arch	10.7	33.8	0.21	136
Butchers	1934	Concrete arch	25.4	68.6	2.47	34.5
Lower Manorburn Dam	1934	Concrete arch with mass concrete gravity abutments	15.9	115.2	0.23	398
Falls	1935	Rockfill embankment with concrete upstream membrane	33.5	155	10.3	365
Conroys	1935	Concrete arch	24.4	61	0.93	24.6
Fraser	1937	Concrete arch with mass concrete gravity right abutment	32	137	4.85	119
Loganburn	1984	Rockfill embankment with concrete upstream membrane	17	100	85	94
	2006	Concrete block spillway 0.4m raising			90	

Note that 1 Mm^3 = 1 x 10^6 m^3 = 1000 megalitres = 1000 Ml

3rd Australasian Engineering Heritage Conference 2009

Interactive Analysis of Arching Masonry Structures

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SUMMARY: *In the modern world, it is often assumed that every structure can be analysed simply to provide thorough understanding of behaviour. Modern computer analyses, however, frequently yield results that are clearly in error, for example, indicating collapse of structures that are behaving well. The paper discusses a range of specific problems with historic masonry structures where expensive finite element (FE) analysis led to unacceptable results and much simpler interactive equilibrium studies showed the structure to be sound.*

The paper is illustrated with bespoke spreadsheet graphical analyses of specific complex vaulted and arching structures.

1 INTRODUCTION

Arches have been used to span openings for at least 3000 years. Throughout most of that time, they were designed by rule of thumb, geometric rules developed and handed down from master to apprentice. The rules were carefully guarded and to a large extent have only become known through back analysis of ancient structures.

When Wren and Hooke were rebuilding London after the fire of 1666 they found it necessary, for the first time, to develop reasonable estimates of the abutment forces and buttresses required. Hooke (1) realised that arches and chains were just mirror images. The concept of the thrust line was born

By 1846, Barlow (2) had demonstrated that we cannot know the true thrust line but that we could be certain of the stability of the structure. This was perhaps the first formulation of the plastic theorems, so it is interesting that the last 50 years have seen a huge argument over whether they can apply to masonry, a brittle material.

The author began work on arches in 1981 by which time Heyman (3) had been publishing in academic journals for 15 years and more but his paper of 1980 in the ICE Proceedings provided an interesting basis for development.

Through the 1980s, graphical analysis was possible on computers, but only using established programming languages. The program Archie was developed at the University of Dundee and became popular in the sphere of bridge assessment in the UK. By the end of that decade spreadsheets were becoming popular and the new formulations developed in programming arch analysis were ideally suited to the new form.

2 SPREADSHEET CONSTRAINTS

Spreadsheets are ideally suited to tabular computation. It happened that the form of calculation developed within Archie is also ideally suited to tabular work. I will begin with some advice on spreadsheet use from accumulated practice.

2.1 Core calculations

Spreadsheets are computer programs like any other and subject to similar errors. In the battle to produce error-free code it is necessary to employ well-established tactics. Perhaps the most important is never to write a long formula in a single cell. There are thousands of cells available, they cost nothing, calculations are just as well done in small steps.

Great care should be taken in developing calculations so that addressing is clear and unambiguous and that each calculation can be replicated for the next element of the structure without any retyping.

2.2 Graphing

The facilities for graphing within Excel spreadsheet program are extremely powerful. It is possible to produce output that looks very much like an engineering drawing. Perhaps the most important capacity is the ability to lift the pen by simply missing one line in a column of plotted points. This can also be achieved conditionally by putting "#N/A" as text in a cell. Attempts to blank the cell using "" are seem to leave something not recognised as a blank by the graphing routines.

2.3 Choices

When programming, it is often necessary to make choices. The IF statement is very powerful but also very easy to miss-program. It is much more secure to make a truth table, for example by saying =A>B, and then use the outcome within an IF statement.

	A	B	C	D
7	=A5<B5	=B5<=C5	=AND(A7,B7)	=IF(C7,

Table 1 *One row of a Truth Table*

3 CALCULATION PROCESSES

3.1 The meaning of the thrust line

The thrust line forms the locus of the centroid of compressive stress as it flows from section to section. Thrust lines only work in the essentially skeletal structures. The results are sensitive to the choice of divisions between the sections as will be illustrated below.

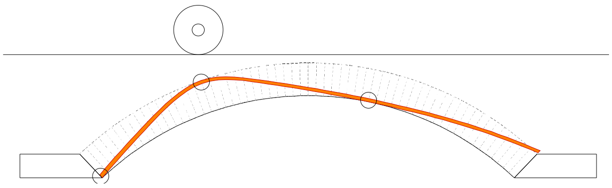

Figure 1 *A thrust line for an arch bridge*

The simplest view of the calculation process is that it relates directly to computing the stability of the masonry retaining wall. Moments are taken about a specific point and divided by the force normal to the section. In circular curves it is convenient to take moments about the centre of the circle. If the curve is more complex the scheme of axes must be developed specifically and moved for each segment.

3.2 Vector format calculations

In Britain, at least, it remains uncommon for Civil Engineering students to be taught to use vectors in their calculations. In two dimensions, the vector format offers an number of simplifications in the algebraic side of calculations. Once a move is made to three dimensions the benefits become substantial. It is perhaps appropriate to introduce the calculation methods used in the work described below. Some of the steps are very simple.

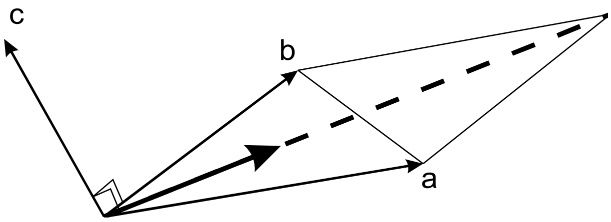

Figure 2 *Area and centroid of a triangle*

$$c = \begin{vmatrix} i & j & k \\ a_x & a_y & 0 \\ b_x & b_y & 0 \end{vmatrix}$$

The area of a parallelogram bounded by two vectors is the cross product of the vectors. It is a vector quantity, having direction normal to the plane of the two vectors. The direction of the vector product depends on the order of multiplication so that a random polygon area can be described by the vectors to the corners and the area of the polygon found by taking the cross products of the vectors in sequence. The signs of various partial areas take care of themselves.

In Figure 2, **a** x **b** is the area of the parallelogram and is the vector **c** The area of the triangle is thus |**c**|/2. If the product is taken as **b** x **a** the product is –**c**. The centroid of the triangle is at (**a** + **b**)/3 Strictly, of course, this is (**a** + **b** + **0**)/3, the three vectors describing the three corners.

In three dimensions the equivalent form is the tetrahedron.

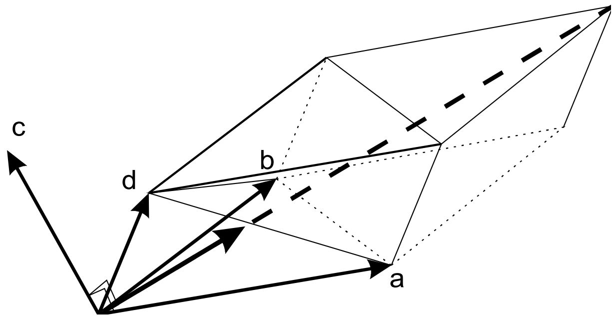

Figure 3 *Volume and centroid of a tetrahedron*

In Figure 3 the vector **d** describes the third dimension of a parallelepiped. The scalar product **c . d** is the product of the magnitude of **c** and the projection of **d** on **c**. Which is the volume of the parallelepiped. The centroid is at (**a** + **b** + **d**)/4.

Perhaps of more significance is the representation of forces as vectors. A force in three dimensional space made up of three components Fx, Fy, Fz is not completely described as the position of the force is significant. If we choose a spatial origin such that the force acts at a point x,y,z, then the position of the force can be defined by its moment about the origin. The moment about the origin is the cross product of the vector defining the force and the geometric vector from the origin to any point on the line of action of the force.

$$M = \begin{vmatrix} i & j & k \\ F_x & F_y & F_z \\ x & y & z \end{vmatrix}$$

Two forces defined in this way can be added by simply adding the six components Fx, Fy, Fz, Mx, My, Mz.

It is perhaps becoming clear that this form of calculation lends itself to tabular presentation and thus to calculation in a spreadsheet.

3.3 Three dimensional thrust diagrams and the Wrench

Robert Hooke (1) conceived the thrust line while he and Christopher Wren were rebuilding London's Churches after the great fire. It is a very powerful tool but has some very strict limitations. The first of these is that it only works in skeletal structures. There is very limited value (and great opportunity for confusion) in drawing thrust lines through a continuum. This is perhaps best illustrated in a domain where two thrust lines meet, something that Brunel dealt with in his analysis of the Maidenhead bridge

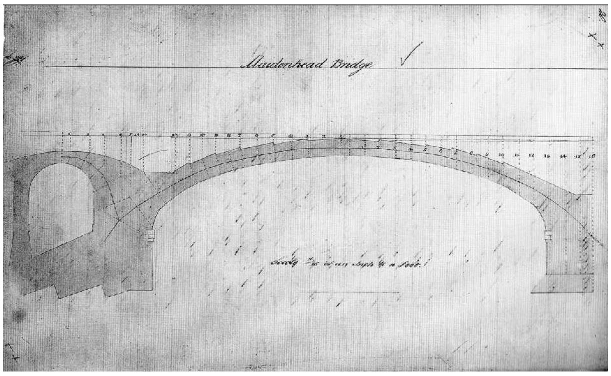

Figure 4 *Brunel's trust lines for Maidenhead*

The bifurcated thrust at the left of the main arch in Figure 4 actually tells us nothing. The flow of force is entirely dependent on the lines on which the structure is divided. This is well illustrated by considering thrusts in a vault in a Scottish tower house. The vault is semi-circular and 5m span with walls nearly 1m thick, so the material through which the thrust is to be plotted is essentially a continuum rather than a skeleton.

A spreadsheet was built in which the structure was divided radially into segments but the centre of the divisions could be moved down from the centre of the semi-circle to a point up to 50m lower. In this latter scheme, the divisions are approaching vertical slices.

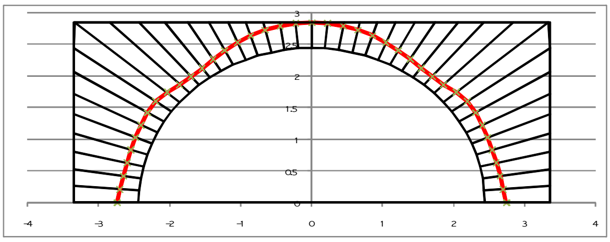

Figure 5 *Thrust line through a substantial structure divided radially*

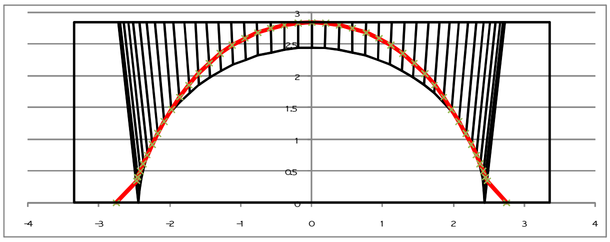

Figure 6 *Thrust line through a substantial structure divided almost vertically*

Note that in both Figure 5 and Figure 6 the thrust begins and ends, and passes through the crown at the same point. The overall stability is not changed, it is simply that it becomes impossible to trace the thrust through the sections. In arch bridges, this is overcome by the often false assumption that the arch is the entire structure and everything else acts upon it as load or reaction.

In the discussion so far, the issue has been entirely in two dimensions. If we make an arbitrary cut through a three dimensional structure, we have seen that the forces acting across the cut can be represented by three components of force and three of moment. WE may choose a local set of axes so that two lie in the cut plane and one normal to it. We then have a normal component and two shear forces, moments about two axes in the plane, which can be represented by placing the normal force in an appropriate position, but there remains a moment about the normal axis. In those few areas of structural teaching where this problem is discussed, the general form of a force is called a wrench. That is a force in a particular position in a specified direction but with an associated twisting moment about the line of action. The first example below is of a skeletal stone structure in which the wrench cannot reasonably be ignored.

3.4 Interaction and its validity

In 1846, WH Barlow (2) set out his views of the way arches behaved. He made a practical (Figure 7) demonstration of the fact that the thrust in an arch might take any one of many lines and that the engineer could not expect to show which one was "correct". This is perhaps the earliest expression of the plastic theorems which didn't otherwise appear in the UK until Baker (5) returned from the IABSE symposium in 1936.

***Figure** 7 A replica of Barlow's model showing how unpredictable a thrust line is*

Half a century later, Castigliano (6) developed a scheme for the elastic analysis of indeterminate structures. Using hand calculation he used this system to analyse masonry arches, progressively removing (or replacing) any material that went into or came out of tension as the iterative process proceeded. He recognised, though, that his analysis was critically dependent on the boundary conditions and that in the limit, the analysis produced a mechanism at failure which could be arrived at directly with much less effort.

In many circumstances, it is useful to explore the range of thrust lines that might be appropriate in a structure. The easiest way to do this is with interaction. Allow the engineer to vary parameters and explore the effects. This is a much more powerful process than might first appear. Certainly much more so than computer optimisation of structures with which a direct comparison might be made. The engineer maintains direct and continuous contact with the exploration of equilibrium.

Modern spreadsheets offer very powerful tools for building interactive analyses. Scroll bars, spin buttons, radio buttons and check boxes all have their place. Figure 8 shows a range of tools in use. Placing radio buttons in a box automatically connects them so that it is possible to choose a shape and the end conditions for an arch independently.

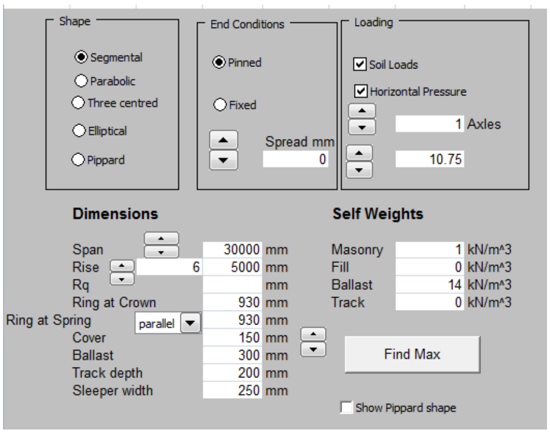

***Figure 8** A selection of tools used to add interaction to a spreadsheet*

4 EXAMPLES

4.1 Wells Cathedral

In the cathedral at Wells there is a flying buttress that has been seriously modified. Where it used to reach the ground as a substantial masonry pier it now lands on a vaulted ceiling with a small column below. To complicate the issue the column is not central under the buttress. The buttress therefore slopes sideways to land on the centre of the pier (Figure 9).

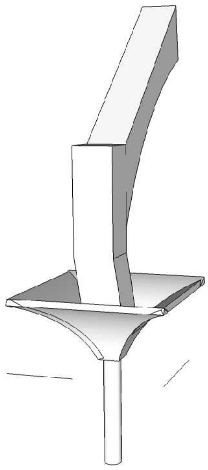

***Figure 9** View of the buttress and vaults*

The model was constructed in Excel. The buttress, vaults and column have a dominantly vertical aspect so they could be divided into horizontal slices. Each slice was represented as an octagon. The volume was built up from a set of tetrahedra for which both volume and centroid are easily calculated. Sections which did not require an octagonal model were represented by making some nodes co-incident.

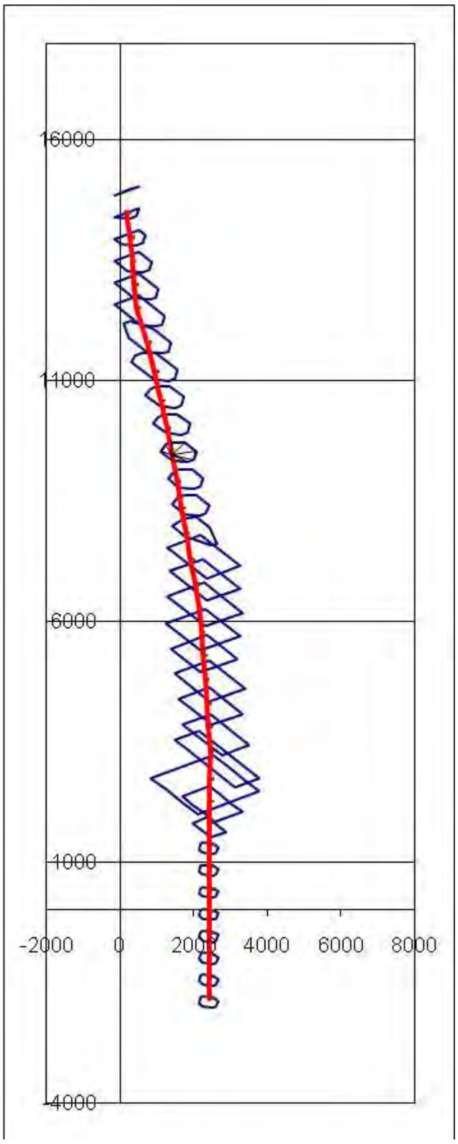

Figure 10 *A 3D view of thrust in the Wells Buttress*

This model illustrates a number of features available in Excel. The buttress itself is only part of the structure. Forces are applied in the top and transmitted through it to the ground. The model allows the engineering to apply appropriate forces at the top of the buttress and computes the flow and then displays it in several ways. The two-dimensional graph is a representation of a three-dimensional structure and using scrollbars it is possible to rotate the image about each axis.

Despite this ease of manipulation, it remains very difficult, if not impossible to visualise the flow of force through the structure in this form. In Figure 10, one slice contains a spider linking the corner nodes with the appropriate node on the thrust. This helps a little, but a direct cross section is also needed.

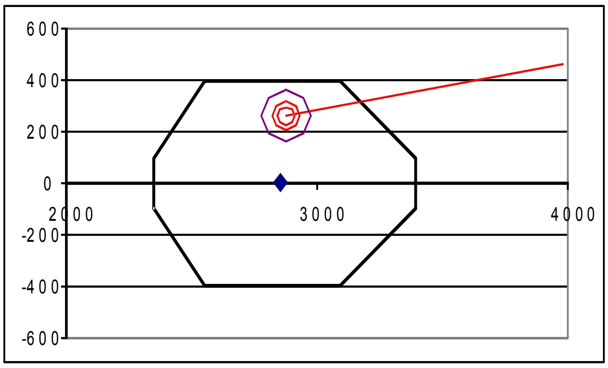

Figure 11 *A plan view of the selected slice from figure 8*

The section shown in Figure 11 shows the position of the centroid of the section and the point of action of the normal force. The in plane forces are represented by a vector showing magnitude and direction. Three rings surround the point of the force. The inner circle contains an area big enough to sustain the whole normal force. The thin annulus around it is capable alone of resisting the shear forces. The final ring, if it contained shear force circling the centre, would be capable of resisting the torsion on this face. Thus, this diagram is capable of showing that the structure is (at this section) able to sustain the full system of forces applied.

4.2 Removing a span of an arch bridge

There are many arch bridges on the UK railways. Occasionally it is necessary to modify one span. In this case the bridge was highly skewed and the central span was made up from separate ribs. A side span was to be removed and replaced with beams. It was necessary to demonstrate first that the main span could stand without the side and then that once the beams were in place the bridge could function properly.

An initial model was made using the Archie program. In this model the beam span was modelled as a flat arch. This produced an accurate representation of the weight of the span but with a substantial thrust.

The output from Archie was then fed into an Excel spreadsheet (Figure 12) for further manipulation. In the spreadsheet model it was possible to remove the thrust from the side span and to move the reaction from the beams to find the best combination of span weight and support.

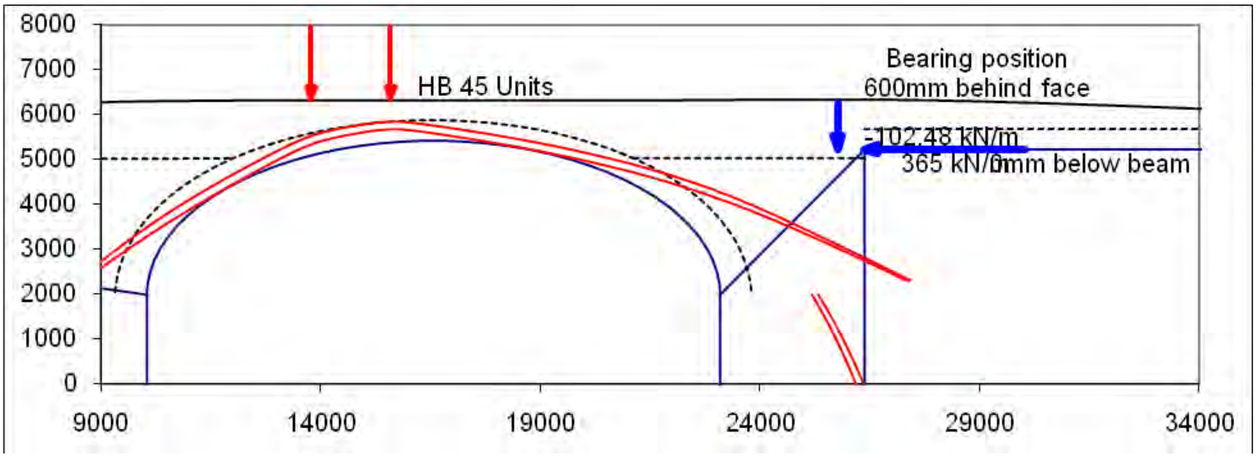

Figure 12 *Thrust layout in a bridge with a beam span, plotted in Excel*

4.3 Clerkenwell house of detention

The third example is a very complex structure. It is the basement floor of a disused and demolished prison. It was built in the late 1700s. The space above is now a car park and is accessed by heavy lorries. The floor was not designed to carry such loads but has been doing so for some years. To bring the basement into use as an office it has been necessary to analyse it for the ability to carry heavier live loads.

The most complex part of the structure consists of a central barrel vault of 4m span and 0.6m rise which is supported at each edge on the wall which is in turn pierced by arches. Behind the wall is a row of 2.1m span vaults spanning in the opposite direction.

Figure 13 *General view of Clerkenwell vaults*

These vaults are also supported on dividing walls which in turn are pierced by arches. The whole area is of some 9m x 7m. The vaults are one brick thick, the walls one and a half brick thick and the arches are supported at the intersection on granite columns which are octagonal and 330 mm wide. Figure 13 shows a view through the side arches into the main area. Figure 14 is a plan view of the critical area showing the layout of vaults and possible loads.

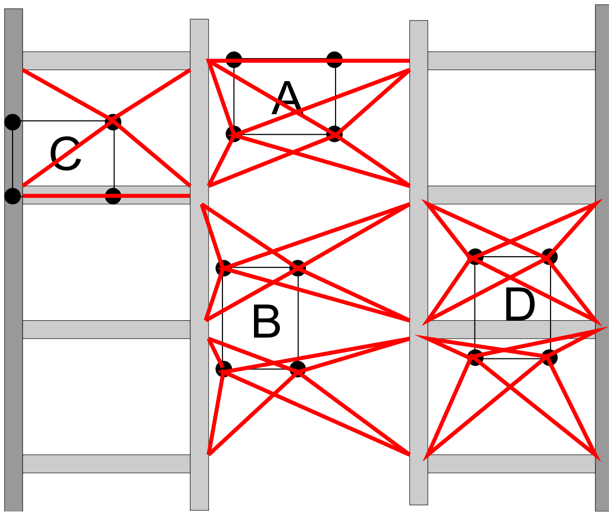

Figure 14 *Plan view of vaults showing load paths*

The analysis considered the possibility of wheel loads over stressing the vaults, of the vaults overturning their abutments and conversely of the archers exerting too great a load on the edge of the vaults causing them to fail.

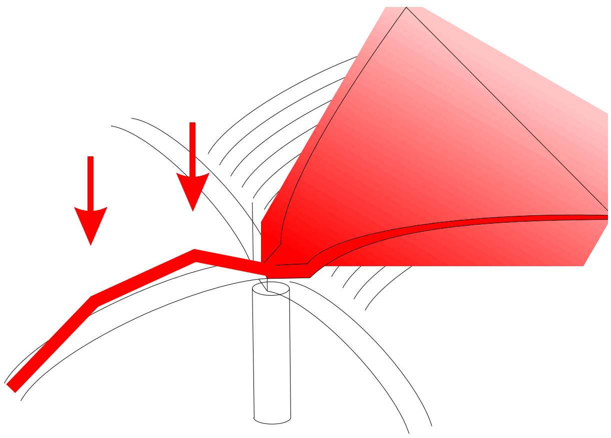

Figure 15 *Side arch load transmitted to vault*

In order to complete this analysis it was a necessary first to envisage a pattern of distribution of stress within the vaults. The model is complex but still works well in

6

Excel. For speed of development it was necessary to keep several parts of the model essentially separate and pass data either manually or by linking spreadsheets.

Figure 15 illustrates how the thrust from the side arch might be distributed in the main vault. Figure 16 illustrates transmission through the long wall where a high narrow stress zone must be converted to a low wide one

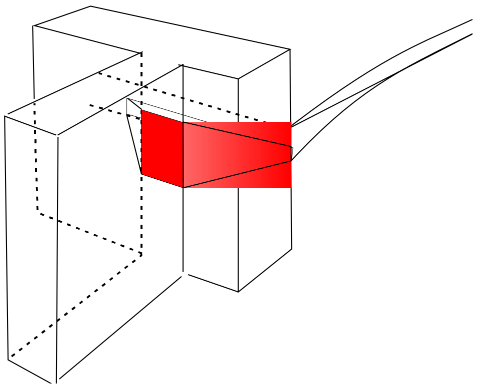

Figure 16 *Thrust transmission through wall.*

Figure 17 shows the effect of transverse distribution (Figure 15) on the thrust pattern in the vault.

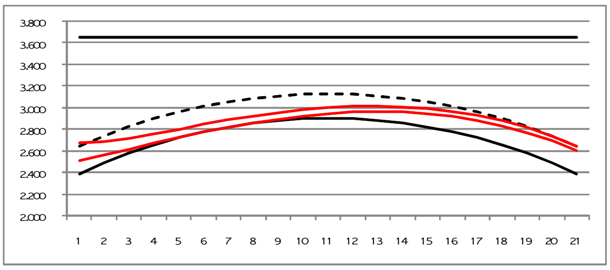

Figure 17 *Effect of distribution of side thrust into main vault*

Figure 18 shows the effect on the side arch of a large load in the main span. Dealing with the reaction to this force on the outer wall is, perhaps, the biggest issue in this work.

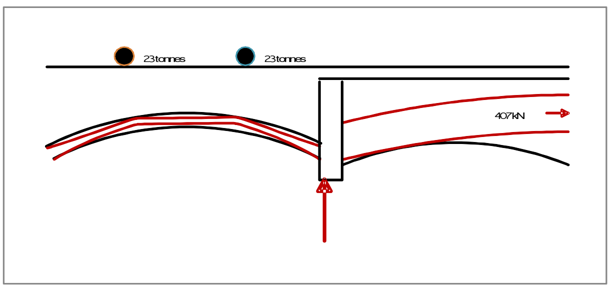

Figure 18 *Transmission of main vault thrust into side arch*

The outcome of the work was to show that the structure is indeed capable of carrying the large loads required but not with the factors of safety one would expect if the building would be occupied.

5 CONCLUSIONS

A review of three projects has shown how it is possible to analyse very complex structures using simple procedures and a powerful spreadsheet. Some suggestions have been made as to how spreadsheets should be structured and how output can be developed. The interactive nature of the procedures is quite different from normal modern analysis. However, it has the considerable advantage of keeping the engineer closely involved with the process.

What has not been made clear, though it is undoubtedly true, is that the powerful modern tools of finite elements and discrete elements, though apparently able to produce definitive analyses of such structures, actually rarely deliver what is promised. The modelling process is extremely complex and requires very special skills. Some of the boundary conditions are quite unknown, and the approximations used are usually inadequate. The most common result from an expensive analysis is an indication that the structure is severely overstressed in certain locations.

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3rd Australasian Engineering Heritage Conference 2009

Monitoring and Measuring Historic Masonry Structures

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SUMMARY: *Monitoring masonry structures is fraught with even more difficulty than is found with more modern construction. Masonry is stiff and brittle, movements are small and finding reference points is often difficult. The paper discusses the problems in the context of three masonry bridges where behaviour was unsatisfactory but difficult to diagnose. The benefits of short term deflection measurements will be discussed and some measuring techniques presented. These include very simple deflection measurements set up to reveal patterns of response to normal traffic loads, optical techniques for displacement measurement in places where a local datum cannot be provided and the use of high sensitivity Tell Tales for crack monitoring.*

1 INTRODUCTION

Masonry structures are very stiff, chiefly by virtue of the large sections involved. For modern engineers, trained on small sections where bending often predominates, the stiffness presents difficulties in conceptualising behaviour. There is a tendency to forget that the real issue is relative, not absolute stiffness. Designing systems for monitoring behaviour depends on first establishing an understanding of likely behaviour and then finding appropriate means for measuring. Stress measurement is probably the unattainable ideal and strain measurement is often used as a surrogate. However, strain measurement is rarely effective, even in homogeneous materials. In masonry the value of the output is likely to be very small.

Measurement of movement requires a datum from which to measure. Vertical movement can often be measured using the ground as a datum. Horizontal movement is much more difficult since a rigid horizontal datum some distance above the ground is singularly difficult to achieve. Different techniques are needed for short term and long term movement.

2 DEFLECTION MEASUREMENT

2.1 Short term vertical deflections

Electrical gauges are nearly always the easiest to deploy and most effective to read. In bridge work there is more to be gained from patterns of deflection than in absolute values. Applying controlled loads is, however, often difficult and always expensive. For this reason, a scheme has been developed for measuring deflections under normal live loads. The basis of the system is a relatively cheap linear potentiometer (1). These devices have very high sensitivity. They are not as stable as linear variable differential transformers (LVDTs) but are very much cheaper, so using them for measuring live load movement allows the use of a much larger number of gauges. For field work, these gauges are coupled to a Datataker DT800 (2) high speed, robust datalogger. This device can read up to 42 gauges at up to 100,000 readings per second. For normal purposes, the primary frequency of deflection of a railway bridge is about 1Hz. By measuring deflections at 200Hz on each gauge it is possible to be sure of finding all the primary modes of deflection. Using the logger in its highest speed mode uses a circular buffer that holds 64,000 readings. The reading counter is binary so optimum cycles are produced using 16 or 32 gauges (calling for 42 means the cycle takes 64 clicks, whatever the click period set). With 32 it is possible to store 2,000 readings for each gauge, so 10 seconds at 200Hz per gauge, though slightly slower cycles and longer periods are sometimes appropriate.

Three systems have been used for mounting these gauges. In the initial development, all work was on a series of small bridges of 3.7m span, each of which had a string course immediately below the springing which provided an excellent base from which to measure. A small truss (Figure 1) was made from extruded aluminium sections (3) and the gauges mounted upon it. This meant that the deflections were measured in the arch alone, with no overall deflection of the abutments.

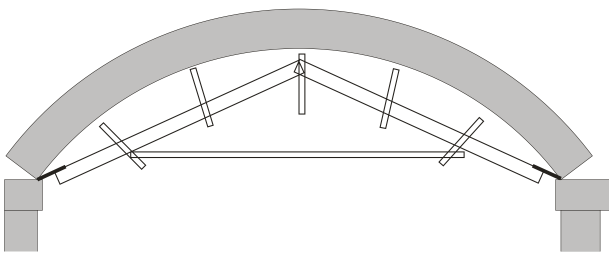

Figure 1 *Mounting frame for gauges*

A second application demanded gauges installed rapidly for a single measurement on a much bigger bridge. Here, drop wires were used, with the gauges mounted on 1m lengths of aluminium angle at the bottom of each wire (Figure 2). Ideally, this system is anchored to concrete blocks and tensioned with bungy chord.

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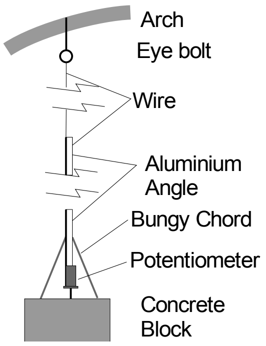

***Figure 2** The drop wire system*

In this way, the tension in the wire remains sensibly constant and one can be sure that the deflection is being measured rather than extension of the wire. Alternatively, if the floor is flat, it is possible to attach weights to the angles to tension the system. Provided weights can be acquired locally, this system is very portable. It has been carried around Britain by train on numerous occasions.

The final development, with even quicker setup times, though slightly less portable, is to use painters' telescopic roller poles to support the gauges. These come in up to 5m lengths and offer the advantage that they can be set up single handed if required.

The outcome, from whatever system is used, is a map of deflections that shows clearly how the forces flow through an arch. Results have demonstrated that skew arches span skew but sway in the square direction, that wide bridges distribute thrust as well as distributing load through the fill on to the arch, that load in one span of a viaduct causes the adjacent span to rise, even that load behind the abutment in a single span will cause the arch to rise.

2.2 Short term horizontal deflections

Measuring horizontal deflections is much more difficult. In some circumstances, where the measurement point is near to the ground, a suitable frame can be erected to provide support. One viaduct, however, presented a particular challenge in measuring horizontal deflections ten metres above the ground. We were expecting deflections in the sub millimetre range so whatever system was deployed had to be very sensitive and stable.

A target was developed comprising black concentric rings 10mm wide and 10mm apart. Using a long focus lens on a video camera, an A4 size target can fill the frame at a range of 40m. It is necessary to hold the camera very still but once that has been achieved, the video can have an overlay imposed generating a Moire pattern which acts as a vernier, magnifying the movement. With this system, it was possible to measure deflections of 0.3mm with confidence and to see the pattern of movement as a train went past. Of course, only one target can be viewed per camera but the instrumentation is very cheap (cameras at about £150) and the moving picture produced is very worthwhile. Actual displacements are measured in individual frames after locating the extreme deflections by scanning through the frames.

Fixing the target proved to be more problematical than we had hoped. Health and safety regulations make reaching 10m up very complex and expensive. In the end we developed a system of mounting the target on a frame and using painters' roller poles to lift the frame into position. The frame was then stressed to the bridge using ropes anchored in the field. The target moved effectively with the bridge. The whole equipment was transported to site on public transport by one person.

Because the target is circular, deflections can be measured in 2 directions. In most circumstances, deflections in the third direction are known to be very small so this is often enough to be useful. One application was measuring vertical and lateral movement of railway track on a 20m span metal bridge over water.

2.3 Longer term vertical movement

Longer term movement requires a permanent reference and long term stable instrumentation. A device is available, marketed as a Movement Gauge (4), which has a short scale graduated to allow it to be read through a surveyor's level to better than 1mm. The scales are attached to elements of a structure that may be moving and to reference points that are believed to be stable. A building owner can quickly be taught how to read the instrument and so keep a record of movement. The manufacturer shows evidence that movement can often be reliably detected in a few weeks rather than the months required with less sensitive instruments.

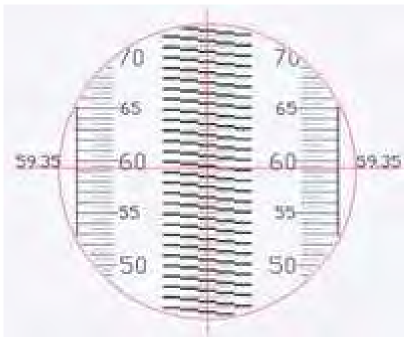

***Figure 3** Movement gauge through a level*

The device is used by reading each movement gauge in turn, including the reference and then subtracting the reference reading from the others. Readings should be taken at short range and, so far as possible, with the instrument equidistant from all the gauges. The length of the gauge has been set to make it as simple as possible to set up the level within the range of each, without producing an intrusion in the appearance of the structure.

3 CRACK MEASUREMENT

Over the years, engineers have employed many systems for monitoring movement in cracks. These range from a simple measurement of crack width, through various forms of telltale to sensitive instruments with gauge points. Gage Technique in the UK (5) make special vibrating wire gauges with springs to allow them to register the greater movements involved in cracks. The earliest telltales were simple glass strips mortared on, or even dabs of mortar over the crack. Neither of these provides more than an indication that movement is continuing and they often fail, becoming detached from the parent material without indicating movement. In the 1970s, Avongard (6) introduced a neat plastic telltale in the 1970s which delivered a great improvement in monitoring.

In 2000, the author was presented with the problem of a railway bridge with cracks which might be moving under live load. Moire Tell Tales were initially developed to deal with this problem but proved to have a number of other valuable applications.

A Moire Tell Tale has 2 parts, a white background with a set of concentric circles and a clear front with a set of circles with slightly different radius. When the two parts are overlayed they produce an interference pattern with three bold rings. When the parts move the rings magnify the movement so that measurements of 0.1mm can readily be made. The boldness of the pattern means that the gauges can be read from a considerable distance (100m is the greatest so far achieved, though further is possible).

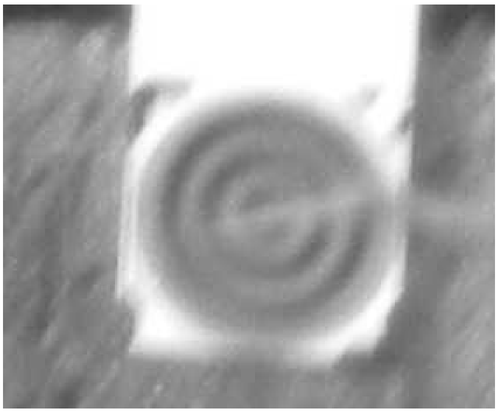

Figure 4 *A Moire Tell Tale set to zero, photo from 100m*

Figure 4 shows the detail of a Tell Tale image. Figure 5 was taken from 100m using a digital camera and a telescope. It shows a Tell Tale with zero deflection.

Figure 5 *Moire telltale showing displacement*

Figure 6 shows the pattern from Figure 5 reproduced on a computer screen with a readout of 0.4mm to the left and 2.2mm downwards.

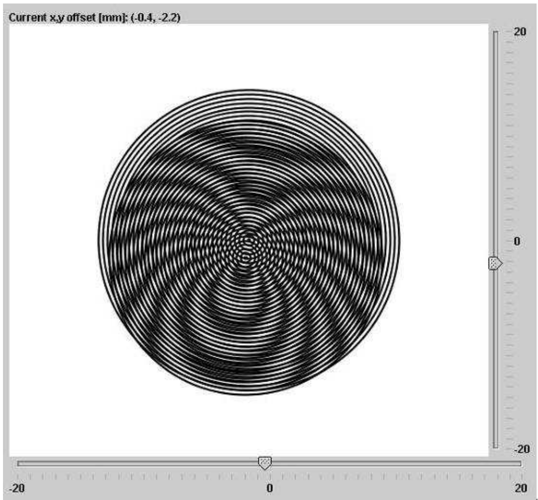

Figure 6 *Computer readout of Figure 5*

4 APPLICATIONS

4.1 Deflections in a small bridge

A small bridge of 3.7m span, 0.9m rise and 10m width carries two tracks of railway. Dramatic changes in load intensity and frequency resulted in rapid deterioration which was not predicted by analysis.

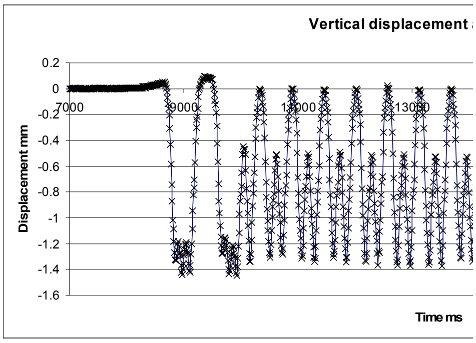

***Figure** 7 Mid span deflection*

On a first visit to the site, the author carried some aluminium tent poles, a linear potentiometer and a computer based oscilloscope. The chart in Figure 7 shows mid span deflection measured with this simple equipment. It shows that the crown rises as the load approaches then drops as loads pass over the bridge. All three axles on the locomotive bogie show clearly. The spacing of the bogies is so great that the loco straddles the bridge completely pushing the abutments together and generating maximum rise.

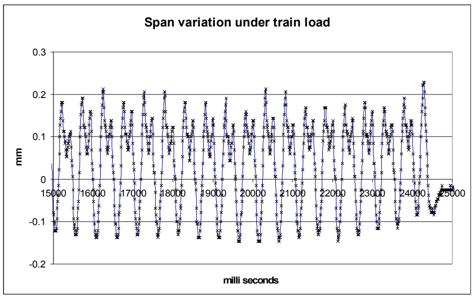

***Figure 8** Span change*

Figure 8 shows the result when the same very simple equipment was mounted to measure span change. Note that the span reduces as a load approaches then increases as the load comes on to the bridge. This graph has no proper zero because the equipment slipped in use, but the form of the graph is conclusive.

The encouraging results from these individual measurements led to a greater investment in equipment. The crack pattern suggested that the loads were not affecting the arch in the assumed way and a measurement of deflection pattern was proposed. 30 gauges were used in 6 rows of 5 through the span. They were mounted on aluminium frames which, in turn, sat on a string course of stone at the arch springing level.

The full output can be viewed as video but the snapshot in Figure 9 shows the deep hollow under the load and much more distributed (and smaller) rise on the far side of the span.

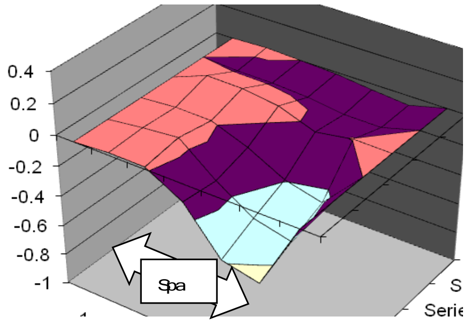

***Figure 9** Deflection pattern*

The arches exhibited sway, as was anticipated, but the sway pattern was interesting in two major respects. Large deflections occurred under the load on the upstream half of the bridge but the corresponding upward deflection on the downstream side was much smaller and more broadly spread.

4.2 Lateral movement at the top of a high pier

It had been suggested that the bridge in question (Figure 10) was moving by a more than acceptable amount. The recorded movements were actually less than 0.5mm but there was considerable doubt about what movement had been recorded. It was proposed to measure deflections under moving trains at the top of one pier to confirm that the actual movements at deck level were small and the bridge was actually sound (as it appeared to be).

***Figure 10** A viaduct declared to have excessive movement*

Measuring lateral deflections at the top of the pier, 10m above the ground presented considerable difficulty. There were two major problems, access and a firm reference. Some experimentation showed that a cheap video camera could resolve a patterned target with sufficient accuracy to be used for measurement. By videoing the target as a train went past, then overlaying a stationary pattern on the video, a Moire pattern was developed which could be observed in movement and measured accurately at individual frames.

Figure 11 *Preparing the target for lifting*

To mount the target, it was attached to an aluminium frame which had three spiked anchors and attachments for two tie-back ropes. Two painter's roller poles were connected back to back and this enabled a roller to be positioned on the string course at the springing level (Figure 12)

Figure 12 *The target in place*

Once the target was in position, the tie back chords were anchored to a peg in the field behind the pier and tensioned to clamp the frame firmly to the brickwork.

The video camera was taped to a block of concrete using insulating tape and the block then adjusted until the camera pointed at the target. A camera with a 40 times zoom lens was chosen and a telescopic doubler lens added this giving an effective focal length of about 2.8m. The camera was positioned on the ground 40m from the target.

Figure 13 shows the image of the target as it appeared in the video and Figure 14 shows the result of adding an overlay to produce a moire pattern. The instrumentation proved to be absolutely steady even in a gusty wind and movements of the order of 0.3mm were readily measured.

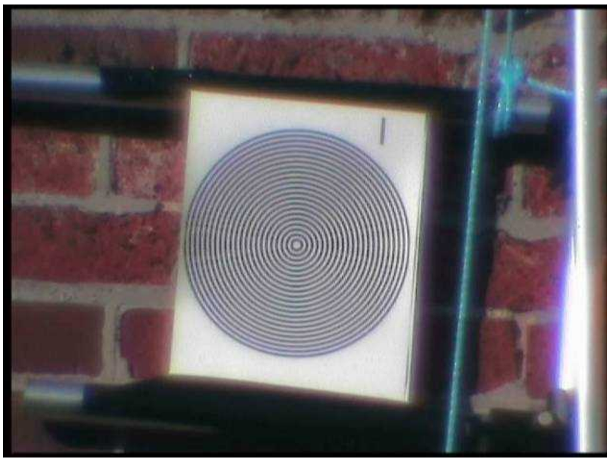

Figure 13 *The target through a video camera*

Figure 14 *Target from Figure 13 with static image overlayed*

4.3 Movement between rings in a brick arch

The third example involves a brick viaduct in which there was evident movement between the rings of the arch. Ring separation was diagnosed and it was proposed to stitch and grout the whole ring, despite the fact that other rings in the same viaduct had been treated in this way without any noticeable change in behaviour.

A series of Moire Tell Tales were attached across the crack and videoed as a train went past. This showed that the movement in the crack was entirely radial. A sample video is posted on YouTube (7). Such movement is not diagnostic of ring separation so an alternative hypothesis was sought.

Brief study suggested that the arch ring was actually intact over much of the width of the bridge. To confirm that the rings were intact further in, cores were taken progressively through the rings and a depth gauge used to confirm that the surface and the bottom of the whole were moving together (Figure 15).

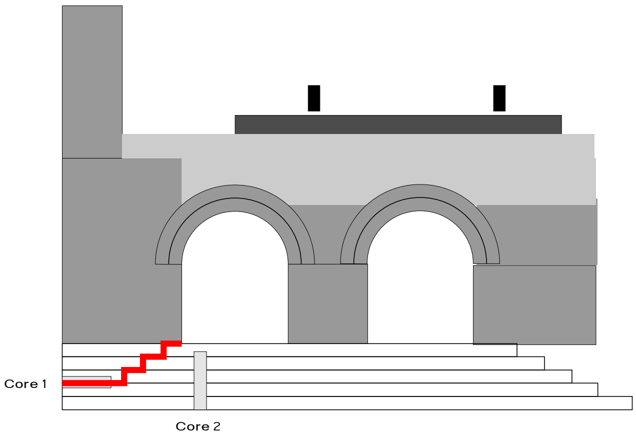

Figure 15 *Cross section of arch showing likely form of fracture*

5 CONCLUSIONS

Measurement of structural movement is becoming much simpler. A range of possibilities have been described and applications indicated. The value of such measurement is, however, utterly dependent on interpretation. It is never sufficient to go out and measure and record. It is vital that a hypothesis of behaviour is first developed, then a system for testing that hypothesis is proposed before any site work is begun. Once the data has been retrieved, it is often necessary to carry out substantial analysis to develop a full understanding of behaviour.

6 REFERENCES

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Archaeology and the Industrial Landscape: 21st Century Adaptive Redevelopment Confronts 19th Century Industrial Heritage

Peter Holmes MA, AAAssoc., Sinclair Knight and Merz (SKM).

SUMMARY: *The development of transport networks in Victoria were driven in part by the gold rush, closer settlement schemes and pastoral developments which all had a major impact on the physical and cultural landscape by the late 19 century. By 1890 the Newport Railway Workshops in Melbourne were established as the focal point of the rail transport network and rail industry in Victoria. Clearly many historic industrial places, structures and technologies from this period have now become redundant, lost, obsolete or physically decrepit.*

Large scale historic industrial sites such as Newport are becoming the locus of redevelopment projects and hence their significant social and engineering heritage components become the subject of statutory planning and heritage assessments. The intention of this paper is to examine the practical and theoretical aspects of the assessment and conservation processes involved with the potential development of the former registered industrial heritage site Newport Railway Workshops.

1. INTRODUCTION

The purpose of this paper is to examine an industrial landscape remnant in Victoria that has recently become the locus of an adaptive redevelopment scheme. It was arguably a primary component of a mid 19th century economic revolution in Australia signalled by the arrival of a new energy regime and the rapid transformation of the social as well as the natural landscape. The dynamic convergence of this new form of energy and transport is an ideal setting according to Rifkin (2009) for an economic revolution and provided the nexus for an economic revolution for the state of Victoria.

More importantly, the arrival of a new energy regime was not only concerned with the exchange of ideas and materials but with the transfer of the ownership of those ideas and materials (McNeill 1988) which was soon followed by their transformation and innovation.

The stage was finally set for large scale industrial developments in Victoria when political autonomy for the colony was granted just months prior to the gold rush in1851. Political autonomy and the creation of wealth was critical at this time for the creation of state institutions necessary to initiate and manage large scale infrastructure projects in the transport sector of the economy. Unlike Britain, the Australian climate and topography was generally unsuited to support industrial development based on water power (Rosenberg & Trajtenberg 2001). Compared to steam, water still offered the most abundant and cheapest form of energy in the nineteenth century in the rest of the industrialized world, but despite the high cost steam became king.

The high level of trading communication already established between the industrial core and the colonial periphery of the empire enabled the transfer and diffusion of the latest technology and knowledge back to a fledgling settlement in Australia. Direct transfer of technology occurred with the importation of the first locomotives which were built in England in 1855 and were working in Victoria by 1856 (Lee 2007 p.21) just 25 years after the prototype “Rocket” was completed. Technological development however also requires other essential items such as capital, labour, and institutions which could be borrowed or imported creating in turn a certain degree of dependency at the periphery. Technological dependence thus became structurally entrenched in the nineteenth century economy. Certain constraints developed briefly however as a consequence of British interests aligned with the primary export sector and the early development of a mature industrial base (Rosenberg & Trajtenberg 2001). Technological independence was soon realized in a grand manner with the design of locomotives in 1870s and the opening of the Newport Railway Workshops in 1890.

Although transport systems represented a substantial investment in capital works, confidence in the potential returns from the growth of investment capital was evident in the rapidly expanding rail system and rural development reflecting positive growth in the state economy supported by new political and economic institutions.

Although their historical significance is already clearly established the following chapters will examine the archaeological heritage of the Newport Railway

Workshops as the impact of redevelopment threatens their historical integrity and the extent that the principles of heritage management can ensure that the "past has a future" (Gilmour 2007). The chapter sequence includes firstly the project brief, followed by a brief historical background of the Newport Railway Workshop facility from its inception and diffusionist origins in British industrial facilities. The archaeology of the proposed development is examined in chapter three and then chapter four looks at the Principles of Heritage and Significance Assessments of archaeological features. Chapter five presents the permitting process and a summary of the impact of the proposed works on archaeological features and heritage values associated with the site along with recommended management options. Since the project is still in progress, the addendum outlines the most recent progress of the works.

2. THE NEWPORT RAILWAY WORKSHOPS: INDUSTRIAL REDEVELOPMENT AND HISTORICAL BACKGROUND

2.1 *Project Brief*

The former Newport Railway Workshop facility represents the extant industrial fabric of the former Victorian Railways established in 1884 on a 62.6 Ha vacant block of land 8km south of Melbourne. The site was listed on the Victorian Heritage Register (VHR1000) after an engineering and conservation survey report by C & M J Doring Pty Ltd in 1988. In 2008, Sinclair Knight and Merz were commissioned by the Department of Transport to design an additional stabling facility at Newport to accommodate new suburban rolling stock and facilities. Although the proposed stabling tracks and associated structures did not impact any Heritage listed structural features, a large proportion of the curtilage area, including the former yards and land surrounding the complex was involved as well as a "lean to" structure recently added to the north end of the Tarpaulin Shed. At this point, as senior historical archaeologist for the Sinclair Knight Merz (SKM) Cultural Heritage section, I was asked to undertake a detailed archaeological assessment of the impact area given the close proximity of a heritage listed building and the archaeological potential of the place. The assessment would also include recommendations and appropriate heritage management options.

2.2 *Historical Background*

The history of the Newport Industrial complex is one of continuing growth and capability from the inception of the first rail line from Spencer Street (Batman‟s Hill) to Williamstown pier in 1859 (Doenau 1979, p249). The first locomotives imported from England were unloaded here and assembled at a workshop facility established at the pier. Very soon however, as private rail enterprise expanded with various rail acquisitions in the 1870s it soon became apparent to the newly established Minister of Railways that the Williamstown Workshops were no longer adequate to manage the system effectively.

The Newport Workshops were the response to a decision in 1884 by Richard Speight, the new manager of Victorian Railways, to erect a new facility on a vacant block of land between the Geelong Railway and the Williamstown Railway and Champion Road at Newport. Richard Speight had only just arrived in Melbourne from the Midland Railway, Derby in England where he had been Assistant General Manager since 1877 (Lee 2007). With his appointment as manager of the Victorian Railways at the beginning of 1884 and a new administration he began an era of expansion to overcome the inadequate facilities offered at the Williamstown and Port Melbourne Workshops. Many of the innovations introduced at that time such as new rolling stock and standard locomotive designs were based on Midland Railway practice. The design for Newport was also similar to the Midland Railways Derby Workshop where a central two storey brick office block surmounted by a clock tower was also a dominant feature. This layout may have been originally derived from the design of British Railway Workshops at the London and South Western Co. Nine Elms workshops in the south of England (Doenau 1979, p.251) and subsequently modified by Victorian engineers. The new workshop complex was constructed and equipped between 1886 and 1888. The „Tarpaulin Shed‟ was built in 1887 with an addition to the south added in 1890. The building was again doubled in size in 1912 (Doring 1988, p.5). The original 1890 layout is shown in Figure 2-1.

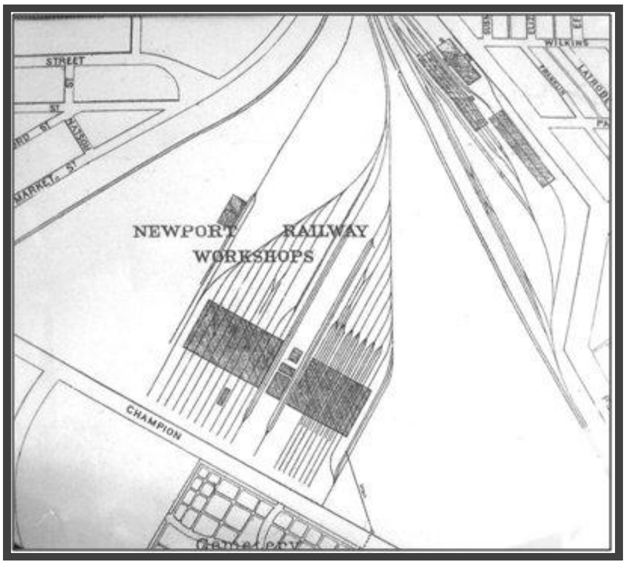

Figure 2-1 *Newport Railway Workshops 1890*(Victorian Railways Survey Plan 1890, State Library of Victoria)

Supply and maintenance of equipment for the Victorian Railways was the principal function of the Newport facility for the first fifteen years. Just one small shunting engine was built during this time in the west block, but carriage construction in the East block had begun immediately the workshops were completed in 1889. By 1904 however as a result of a change in Government policy the "Golden Age" for locomotive building (Doenau 1979, p253) began when Newport won a contract to replace the aging collection of locomotives dating back to the 1860s with a new Victorian Railways design.

Figure 2-2 *Newport Workshop activity ca 1915* ((Victorian Railways cited in Doenau, G., 1979. The Newport Story, Australian Railway Historical Society Bulletin, vol XXX, No.505, p263)

Continued expansion and the introduction of new technology to the Victorian Railway system created a need for still more workshop facilities at Newport especially during World War I (Figure 2-2) when munitions were produced and more importantly the conversion of existing suburban rolling stock to electric traction. As a result of these activities, by 1917 virtually the entire Newport workshop facility had converted from steam to electricity and the Melbourne suburban rail system was electrified in 1919 (Doring 1988). Locomotives continued to be designed and produced as increased capacity and efficiency were necessary to maintain an economic advantage in the transport sector for passengers and goods.

Significant changes continued to occur at various times throughout the operational life of the Newport Stabling Yards and Workshops creating the current collection of buildings and yards which now represents the material culture of an industrial complex which has evolved for around 100 years.

3. ARCHAEOLOGY AND THE FORMER NEWPORT WORKSHOPS INDUSTRIAL HERITAGE

Besides the Heritage Survey carried out by Doring and Associates (1988) no archaeological surveys have been carried out prior to this SKM study.

Under Section 132 of the Heritage Act 1995 any person discovering or uncovering an archaeological relic is required to report the discovery to the Executive Director of Heritage Victoria. An archaeological relic is defined by the Act as:

Any archaeological deposit;or any artefact or material evidence associated with an archaeological deposit which relates to the non-Indigenous settlement or visitation of Victoria and is more than 50 years in age.

In accordance with the Heritage process, Heritage Victoria was notified of the intention to survey the two designated impact areas, A and B. Both areas were covered in a systematic walk over survey and correlated with previously features and structure identifed from historical surveys of the Newport Workshops. Some of these structures and features may or may not have been lost and which could be considered a potential archaeological site.

3.1 *Area A*

Most of Area A (Appendix B) to the north of the Tarpaulin Shed has been used as a stabling yard since 1919 (Figure 3-4). These extant rail lines with their associated points and levers are currently still active and used to store assorted historical museum rolling stock such as carriages and wagons, consequently this area is extensively disturbed and there is no documentary evidence of any prior activity to the installation of the rail network. The north eastern boundary of Area A also marked the curtilage surrounding the Heritage registered Tarpaulin Shop and consequently was considered as a heritage sensitive area (Figure 3-1)

Figure 3-1Heritage sensitive NE boundary, Area A, view south (Holmes P. 2008, „Newport Stabling Yards Baseline Historical Assessment‟, Report, Department of Transport, Melbourne)

The Victorian Railways 1919 map shows two small unidentified features in Area A associated with this area (Figure 3-4) but by 1933 these are no longer extant. Two other features in Area B at the top are an "elevated water tank" and an "excavated tank". Four new ancillary features can be identified on the Victorian Railway (VR) Survey Plan, 1933 (Figure 3-5) associated with the Tarpaulin Shed activities. Identified from the northern end, these features include an unidentified structure approximately 2.8m x 3.5m, a

toilet facility, a Tarpaulin Wash and associated brick drains and finally another small shed of unknown designation. The “excavated tank” has become a “Pond with Guard Rail” by 1933.
The “lean to” structure at the the north end of the Tarpaulin Shed is shown on the 1972 Newport Workshops map (Figure 3-2). This is essentially a stand alone structure and appears to have been added sometime between 1933 (Figure 3-5) and 1972 and is not considered of heritage value. However it is situated within the new Training School track alignment and will be removed.

Figure 3-2Newport Workshops 1972 with Tarpaulin Shed extension ((Victorian Railways cited in Doenau, G., 1979. The Newport Story Australian Railway Historical Society Bulletin, vol XXX, No.505, p261)

Figure 3-3 *Area A view south, standpipe ca 1933 and active line in limited use* (Holmes P. 2008, „Newport Stabling Yards Baseline Historical Assessment‟, Report, Department of Transport, Melbourne)

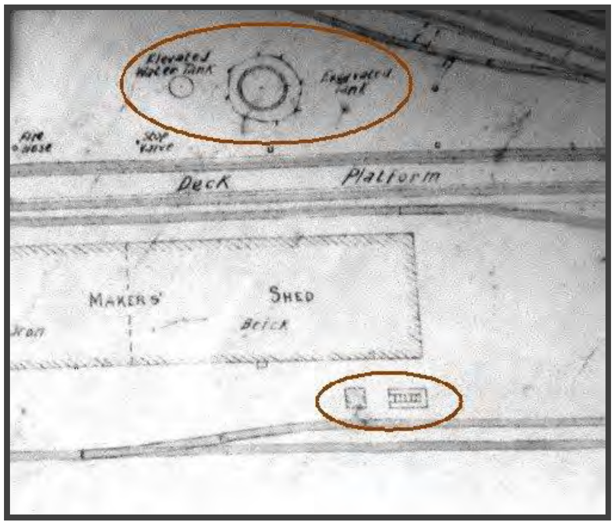

Figure 3-4 *Newport survey plan 1919, showing features in Area A (bottom) and Area B (top)* (Victorian Railways Survey Plan 1890, State Library of Victoria)

Except for the brick toilet facility and the small shed there was no evidence or visible remnants of the remaining two structures and therefore these former features were now considered Potential Archaeological Deposits (PAD). Although both of these early and later features are situated outside the survey area inside the tree line, this north eastern boundary of Area A (Figure 3-1) is therefore considered to be of high archaeological potential.

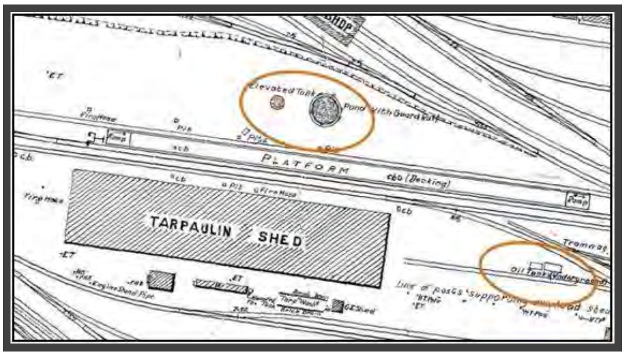

Figure 3-5 *1933 Survey plan with features with Potential Archaeological Deposits* (Victorian Railways Survey Plan 1933. ARHS Railway Museum, Newport)

Area A had recently been subject to clearing activities and items such as storage tanks, historic rolling stock and elements of rail ephemera had already been removed. A Standpipe and various other items that appeared to be in limited use were identified and recorded during the survey.

The Standpipe (Figure 3-3), coaling area and the active line were necessary facilities to maintain the presence of the Steam Rail group and their restored locomotive housed in the north end extension of the Tarpaulin Shed. The points and levers used in this area (Figure 3-7) were installed sometime between 1890 and 1919 according to survey plans. It could not be ascertained whether the set of points and levers currently still in limited use were the original items or whether they may have been subject to modifications or replaced at any stage.

Figure 3-6 *Area A view south east, rolling stock, coaling and storage areas* (Holmes P., 2008, „Newport Stabling Yards Baseline Historical Assessment‟, Report, Department of Transport, Melbourne)

Figure 3-7 *Area A, historic points and levers, ca 1919* (Holmes P. 2008, „Newport Stabling Yards Baseline Historical Assessment‟, Report, Department of Transport, Melbourne)

3.2 *Area B*

Area B is situated to the south of the Tarpaulin Shed (Appendix C) and extends to the northeast as a rectangular corridor, with a fenced stabling line defining the southern boundary along to the current training complex (Appendix A) This area is situated entirely within the heritage registered curtilage area. The northern boundary extends 150m northeast to intersect with the access road and continues for another 116m alongside the road to meet the northern boundary behind the training offices. This is a roughly triangular area consisting of a set of recent buildings, car parks and a large warehouse structure and although it is situated within the delineated curtilage and is approximately 40m from the Tarpaulin Shed it has no potential for archaeological sites or features according to available survey plans. The remainder of the corridor however has several visible features of interest and a high potential for archaeological sites

A section of the 1933 survey plan shown in Figure 3-5 identifies two sets of features shown highlighted which are no longer extant. The two circular features are identified as an "elevated tank" and a "Pond with guard rail" approximately 10m in diameter. The existence of a guard rail surrounding the pond suggests it was probably a hazard, either from the contents or from the depth of water present. Given its proximity to the Tarpaulin Shed and the Truck Paint Shop it could have been used to contain overspill or as a retention area for contaminated fluids, or possibly a water reservoir for emergency fire resources.

No elevated water tank appears in the aerial photo suggesting it may have been an additional utility or connected to the pond resources already available, in which case the photo would have been taken before 1933 suggesting that it was installed sometime between 1919 (Figure 3-4) and 1933. The „pond‟ is also identified in an undated aerial photo (Appendix C).

In addition, to the south of the Tarpaulin Shed, the survey plan identifies two underground oil storage tanks. These may have been installed between 1927 and 1930 along with other major extensions around that time.

3.3 *Summary of the Archaeological Survey*

The results from the archaeological survey carried out for this report in the survey Areas A and B indicates these areas have potential for up to three archaeological sites. The „store" in Area A is historic but is of low archaeological interest. The remaining locations in Area B have been identified from historic survey plans and subject to survey with no surface remnants evident. These two sites located adjacent to each other appear to have been stand alone structures of unknown function although they may have operated as a unit. They will be directly impacted by the works proposed in its present location.

4. CULTURAL HERITAGE ASSESSMENT

4.1 *The Principles of Cultural Heritage Assessment*

The assessment of cultural heritage significance seeks to develop an understanding as to why a study area, place or item is considered important and what values it has to the community. The concept of cultural heritage significance supports that a set of values, beyond financial benefits, is embodied within the place itself, its fabric, setting, use associations, meanings, records, related places and related objects. It can be both tangible and intangible and values may be associated with past, present or future generations (Burra Charter: Charter for Places of Cultural Significance, 1999). Assessments of cultural heritage significance help to formulate and guide management policy and strategies.

Significance assessment for non-Indigenous cultural heritage places in Victoria is guided by the Australian Heritage Commission (2001) definitions of four main categories:

- Historical Significance;
- Scientific Significance (including archaeological);
- Aesthetic Significance;
- Social or Spiritual Significance.

Heritage Victoria has defined a list of criteria for the significance assessment of historical sites and places in Victoria based on the Burra Charter model as follows.

There are two levels of protective significance classification in Victoria which include Local and State. Local significance is legislated through the *Planning and Environment Act 1997*. Places and objects of State significance are protected under the *Heritage Act* 1995 through the Victorian Heritage Register. Archaeological sites with any level of significance can be included in the Victorian Heritage Inventory.

4.2 *The Heritage Significance Assessment*

The archaeological assessment of Areas A and B (Appendix 10) are broadly based on extant features or areas of potential archaeological deposits. In this case, the landscape has been heavily modified by major industrial activity and under regular transformation as various political events and technology have shaped its historical development. Although historical themes relate directly to expansion phases evident in buildings such as the Tarpaulin Shed extension and technological developments associated with the arrival of the Steam Hammer, much of the material evidence associated with these events has been lost or irretrievably modified. Economic viability may be a factor in preservation but most systems and components that could reflect these changes have generally been rendered obsolete and either dismantled or in this instance assumed to be demolished and buried insitu.

4.3 *Assessment of Scientific Significance*

Both survey areas have been subject to continual development and modification for heavy industry since the mid 1880s. Industrial processes are understood to be in a constant state of renewal with a wide variety of factors influencing the rate of redundancy and replacement. The material remnants of these events and processes therefore can provide a valuable contribution to the historical record and an insight into understanding of these processes which might otherwise be lost. The intense scale of industrial activity at the Newport Workshops during World War I is shown in Figure 2-2.
Area A has been relatively isolated from the mainstream of activities and presents a relatively small range of industrial rail related activities offering only limited research potential including:

- Various items including rail tracks, points and levers, related to current stabling activities for the storage of historic rolling stock which are still in occasional use. The engine standpipe is an original feature (Figure 3-3) but will lose its original context when the old stabling and current coaling activities are lost. Therefore it also represents very limited research potential and low scientific significance.

Area B (Appendix10) is situated entirely within the curtilage area and as in Area A, Area B is also comprised of a variety of rail related activities including:

- A set of shunting or stabling tracks were established alongside the Tarpaulin Shed by 1890. A small section will be lost at the south end of the Tarpaulin Shed but besides retaining their original context are considered of low scientific significance.
- An additional set of tracks also parallel to the Tarpaulin Shed are fitted with overhead wiring erected for training purposes as part of the training school included in the survey area are considered of low scientific significance. The signal equipment associated with these tracks

is also considered of low scientific significance.

- A large „pond with guard rail" was a very visible feature in an aerial photo (Appendix C, Undated aerial image of the pond feature first recorded on survey plans in 1919 and last recorded again in 1933. It was perhaps allied to an adjacent building and the Tarpaulin Shed given its size (approximately 10m in diameter) and proximity. It is also situated within the proposed impact area and therefore represents a buried feature of high research potential is considered to have high scientific significance.
- The underground oil tanks (Figure 3-5) are considered to have low scientific significance but could offer some research potential

Overall, considering the potential archaeological sites in Area B, it has moderate scientific significance in view of their possible research potential to contribute toward an understanding of their role in the wider rail manufacturing activities at Newport.

4.4 *Assessment of Historical Significance*

Area A holds few remnants of historical significance except for the „store" as a standing structure and still probably in limited use. The exact nature and function of this building could not be ascertained beyond storage since there was no access. Externally it does not appear to exhibit any special architectural features and is not considered historically significant. A series of ancillary structures now lost along the northwest side of the Tarpaulin Shed were related to tarpaulin production and maintenance and create an archaeologically sensitive area of the boundary. Area A therefore is considered to have low historical significance.

Similarly Area B has few remnants of historical significance and appears to be an area subject to only limited activity. The historic track set alongside the Tarpaulin Shed will be impacted and a further small section at the south end will be lost. The platform, deck and ramps associated with these lines have already been lost and this section is considered to have low historical significance. However further east from the Tarpaulin Shed the locations of three other historic features now lost have been identified as potential archaeological sites and are considered to have high historical significance but the buried oil tanks are considered to have low historical significance.

Area B overall is considered to have moderate to high historical significance for the potential to provide a contribution to the understanding of certain structures now lost, their initial function and why they became redundant and either removed, dismantled or buried.

4.5 *Assessment of Social Significance*

The social significance attached to these particular areas situated within the former Newport Workshops is based on the significance of this context to the rate of development and settlement of the state of Victoria. In these terms the material culture associated with potential archaeological sites and features within these areas may contribute to the understanding of the relationship between social and technological development. Overall, Area A is considered of low social significance while Area B with potential archaeological deposits is considered to have moderate social significance.

5. HERITAGE IMPACT

As part of the Permit for Works application process a Heritage Impact Statement is required to explain in detail the extent of the proposed works and their impact on the Heritage place. The 1888 group of original buildings are of historical significance as one of the best surviving 19th century railway workshops in the world, besides their historical economic significance in the development of Victoria as examined in the introduction. The context therefore of the former Newport Railway Workshops Stabling Yard proposal is an area of sensitive heritage values.

Although the proposed works utilize an area that will have a minimal physical impact on heritage values, the visual impact of modern rail activity will be significant and impose a 21st century complement to the physical presence of current rail heritage related groups and enable historic links with the modern rail network to be maintained.

In summary, the impact from the proposed development will involve six major features:

- The construction phase of the project will create temporary physical and visual disturbance such as increased truck movements for the proposed works. Construction activity will be strictly limited to the proposed construction zone.
- The Stabling Yard proposal has been designed to utilize a vacant area of heritage land and therefore minimize the physical impact but provide visual continuity with rail related activity traditionally associated with the place.
- The adaptive reuse of the heritage place for the Stabling of up to 8 new train sets in the proposed development will activate an additional dimension of compatible rail activities. These will complement the visual and physical presence of current rail heritage related groups and enable historic links with the modern rail network to be maintained.
- Construction will impact three sub surface historic features identified within the construction zone. These features could not be avoided and therefore will be subject to mitigation and remedial measures as outlined below.

- The northern end of the Tarpaulin Shed has a recent "lean-to" addition that will be removed for an access road. This will restore the Tarpaulin Shed to its original dimensions. Some superficial damage may occur during this restoration in which case an assessment will be made and repairs and reinstatement of the building fabric will be undertaken as necessary.
- An additional Stabling facility is also scheduled for construction in the Public Use Zone (Area A) to the north of the Tarpaulin Shed shown in the attached plan (Appendix B, Archaeological Features and Survey AreasThis area had been in use until recently as a Stabling Facility and will necessarily undergo an upgrade to accommodate new track sets. The new facility is considered to create minimal impact except for the construction period with additional truck and machinery movements. However, the curtilage boundary and the works boundary coincide alongside the Tarpaulin shed and need to be clearly identified to prevent any accidental impact upon Heritage assets including possible sub surface archaeological deposits identified in that area.

5.1 *Management Recommendations*

The following recommendations were proposed in the Heritage Impact Statement submitted to Heritage Victoria to mitigate the detrimental impact of the proposed works;

- The mitigation of the „pond" site (Appendix C, Undated aerial image of the pond feature by controlled machine excavation once it is located and the extent and depth of the site is known. It was a significant feature and estimated from survey plans to be approximately 10m diameter.
- The „elevated tank" site may have sub surface features which may indicate a functional link to the „pond" therefore sub surface testing would be recommended.
- The oil tanks will be excavated at the same time, but there may be some environmental concerns to address regarding their removal.
- An assessment of the exposed fabric of the Tarpaulin Shed after removal of the "lean to" structure.
- A high visibility barrier to be erected during construction to clearly delineate the curtilage boundary on the northern side of the Tarpaulin Shed, because there is a possibility of further buried features very close to the boundary, including a Tarpaulin Wash. In addition both ends of the building are at risk from accidental damage during road construction and a suitable buffer zone should be established. The southern corner of the building in particular where it diverts the single lane road and creates a blind corner could require a longer term solution such as a permanent type of roadside barrier.
- The curtilage boundary is to be marked on all plans and maps released to contractors and third party tradesmen as outlined above.

These measures were accepted in principle by Heritage Victoria Council and a Permit was granted for the works to proceed with specified conditions regarding excavations, demolition, a building assessment and the submission of a final report. Final results and conclusions for this project will be presented when excavations have been completed.

6. ADDENDUM

The proposed demolition of the "lean to" extension to the Tarpaulin building has lately attracted the interest of Engineering Heritage Victoria. A recent meeting (16 April 2009) was convened in Melbourne with a view to adopting a strategy of protection and restoration of the Kirkstall Forge Steam Hammer and Billet Crane currently exposed to the elements at the Newport Railway Workshops. I was fortunate to attend this meeting and with my knowledge of the forthcoming program of development I was able to suggest to the sub-committee the possible reuse of structural steel from the "lean to" to establish a structure over the hammer and crane. Following this suggestion a detailed insitu inspection and survey of the available steel was carried out and found to provide adequate structural coverage of the steam hammer site at considerably less expense than the cost of a new structure.

Although the "lean to" structure is not considered a heritage feature it is important to continue the link with rail and the conservation of heritage items at Newport. Sustainability is a core SKM company policy consideration and therefore their full support has been behind the negotiations for the project for the reuse of the "lean to" material.

7. ACKNOWLEDGMENTS

The Australian Railway History Society (ARHS) for providing archival material and SKM for assistance and encouragement and finally the Engineers for Heritage in Australia for the opportunity to present this paper.

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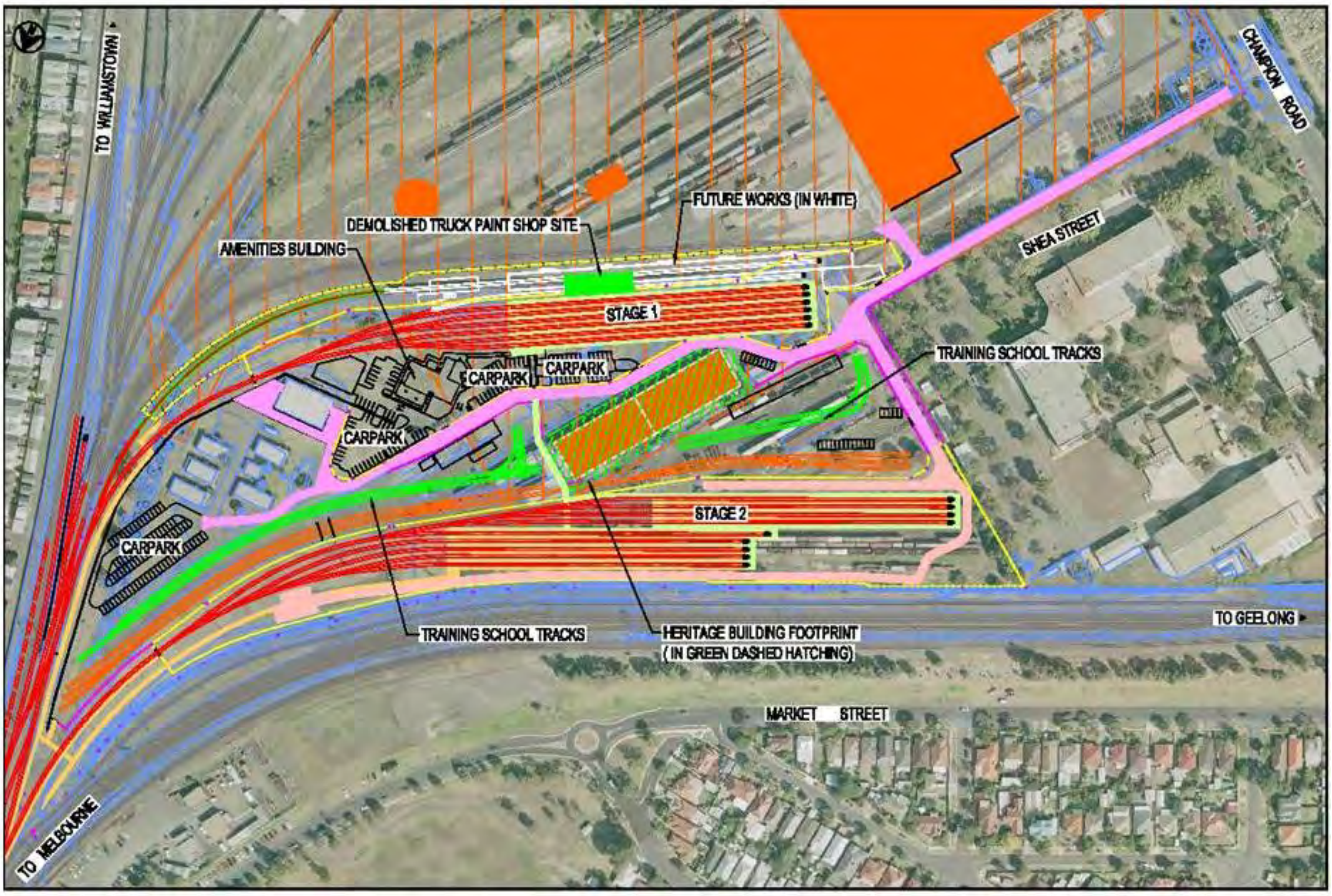
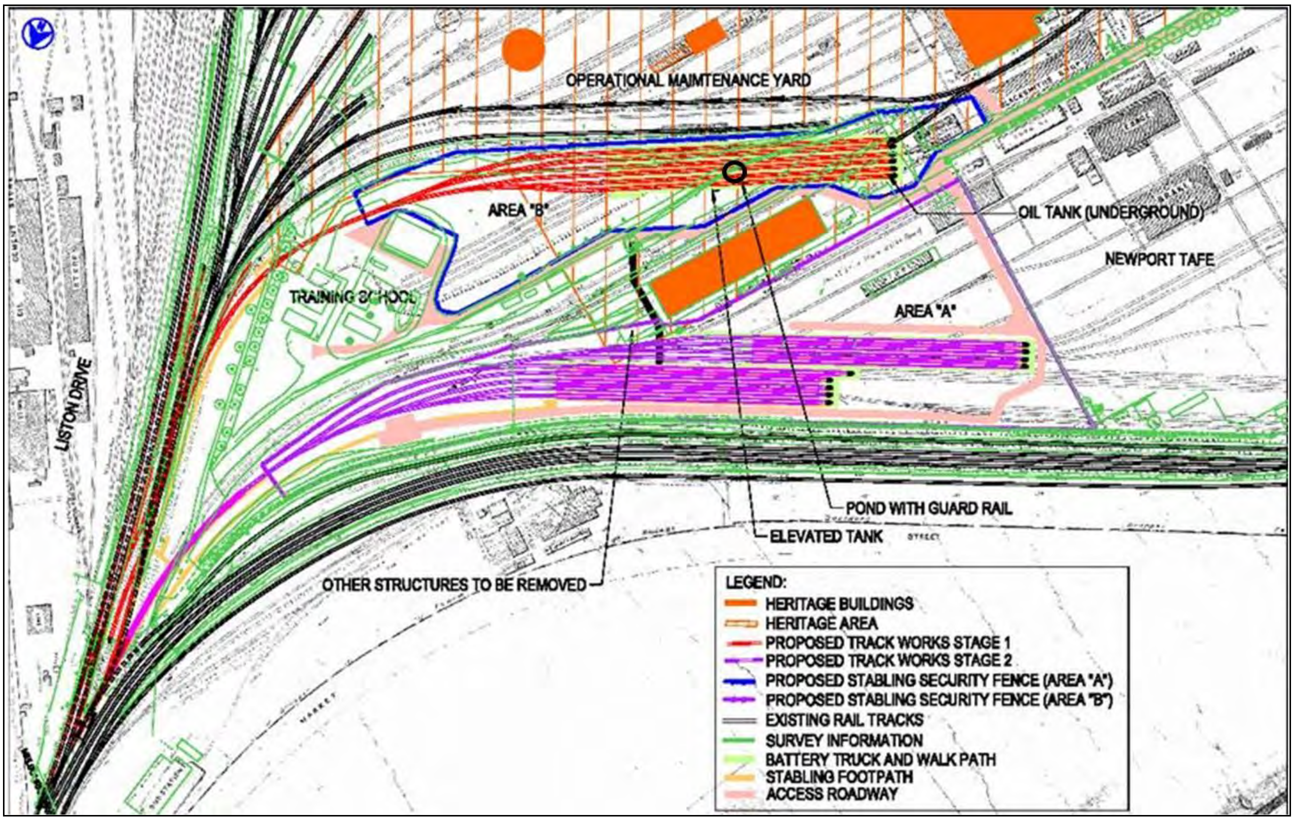
9. APPENDIX A, LAYOUT OF THE PROPOSED STABLING FACILITY AND REGISTERED HERITAGE



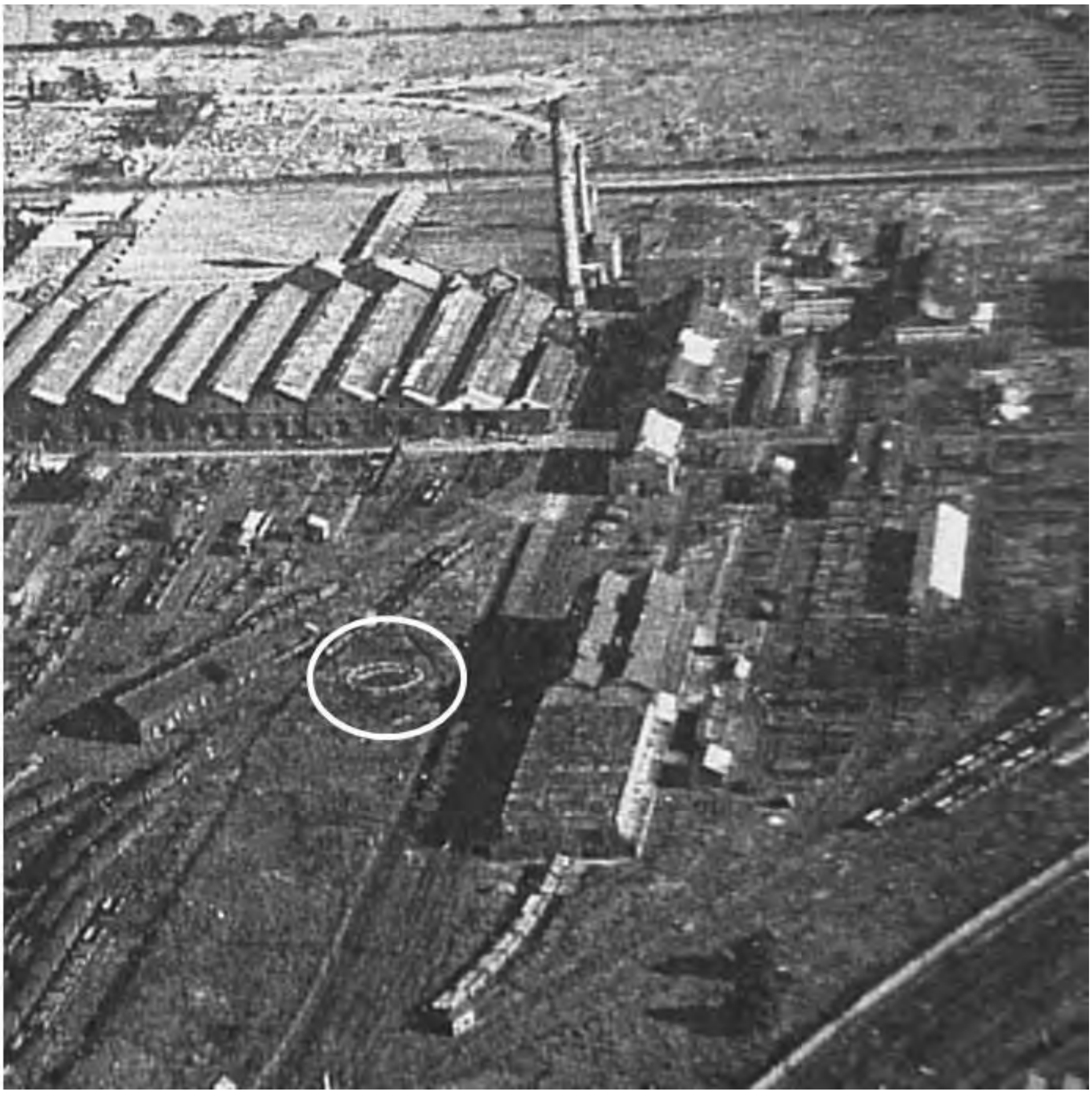
(Sinclair Knight Merz 2009 Newport Stabling Yards Baseline Historical Assessment", Report, Department of Transport, Melbourne)

10. APPENDIX B, ARCHAEOLOGICAL FEATURES AND SURVEY AREAS



(Sinclair Knight Merz 2009 Newport Stabling Yards Baseline Historical Assessment", Report, Department of Transport, Melbourne)

11. APPENDIX C, UNDATED AERIAL IMAGE OF THE POND FEATURE



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3^{rd} Australasian Engineering Heritage Conference 2009

Sydney's Darling Harbour: Two Centuries of Industrial Development, Decline, Transformation and Interpretation

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SUMMARY: For much of the past 200 years the history of Darling Harbour has been embodied in the ships which used it, the shipyards and wharves along its shores and the myriad of factories and warehouses that grew up in the surrounding streets. In the nineteenth century the Harbour was a centre for change and particularly for the introduction of Industrial Revolution technology. It was here that the first steam engine in Australia started work in 1815, here the first iron hulled ship was assembled and here the colony's first foundries belched smoke along its shores, as did the first steamship to be launched. Other important firsts were the Australian Gas Light Company's gasworks, fired up on Queen Victoria's birthday in 1842, and in the next decade Zöllner's galvanizing plant, an important innovation in a country that was to find more ways to use galvanized iron than any other. In 1855 the railway line that ran from the old Central Station along the Ultimo foreshore was part of the first line in NSW. In the 1880s the first hydraulic pumping station in NSW opened and remnants of it still stand as part of an hotel. Around the turn of the century the Ultimo Power Station supplied electricity for Sydney's first electric trams and its neighbour in Pyrmont supplied power to Sydney households through the first reticulated grid.

The Second World War stimulated trade and industry but by the time it ended the coastal shipping trade had disappeared and many industries around the harbour were decaying. This process continued after the war and, although the rail yards continued their growth for a few years, in 1984 the last goods train steamed out of the yards and the industrial history of Darling Harbour was ended. The same year however marked the start of a new era when construction started on the new entertainment and retail precinct which is now the focus of Sydney's leisure scene.

This talk will focus on rediscovering a lost history, and the means of integrating that history into the built environment, along with the adaptive reuse of industrial structures in the vicinity.

Aerial Photographs and the Record of Agriculture and Engineering in Otago, New Zealand

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SUMMARY: *Otago has a wealth of engineering, goldmining and agricultural sites. Aerial photographs are essential to recognise and map sites and helpful in interpreting the meaning of patterns. The patterns may reflect a range of underlying variables such as the exploited resource, the facilities needed to exploit it, transport and social factors such as the supporting settlements, and also modern heritage management issues. Aerial photographs may also be used in illustrating and dramatising sites. Conventional wide-area aerial photographic coverage is useful but, for detail, custom-flown vertical aerials in medium format film and digital media are better. Historical aerial photographs (which date back to about 1945) also have applications, especially where there has been substantial landscape change. On the upper Shotover River, historical processes depended on settlement enclosure and mining capital investment all of which can be investigated using aerial photographs. In addition, examples of aerial photographs of a range of engineering subjects in Otago are shown.*

KEYWORDS: *engineering, goldmining, farming, historic landscapes, Bannockburn, Shotover, Waitaki Dam, Waianakarua bridges, Macraes, Criffel Range*

1. INTRODUCTION

New Zealand has been covered by vertical aerial photographs since mid World War II, flown by New Zealand Aerial Mapping Ltd for the Crown (1). The coverage was repeated up until the 1970s when the last national topographic mapping programme was set up. White's Aviation (2) took a number of large format oblique photographs, many in Central Otago, in the 1950s and 60s. These series comprise a uniquely valuable historical record of the New Zealand landscape which has undergone rapid change since the 1960s. White's Aviation photographs are now available at the National Library and the contact sheet runs of New Zealand Aerial Mapping (NZAM, comprising I estimate 5-10 tonnes of paper) are at the National Archives, both in Wellington.

Today Land Information New Zealand (LINZ) attempts to give national coverage in a programme of digital orthophotos at 1:25,000 scale (http://www.linz.govt.nz/topography/ aerial-images/index.aspx). At best the orthophotos provide a simple layer for use in general Geographic Information Systems (GIS) applications. Many agencies particularly regional and district councils and large land managers commission their own aerial photographs. These photo runs appear to be the source of the better quality aerials on Google Earth.

The key sources for the history of goldmining in Otago are Parliamentary reports and the series of Geological Survey Bulletins (issued from 1890 to 1940) and G.J. Williams (3) *Economic Geology of New Zealand*. In the last few decades, important recorders of the archaeological landscape include Dr Jill Hamel (4), Dr Neville Ritchie (Clutha Valley Project) and Peter Petchey (see below).

2. AERIAL PHOTOGRAPHIC METHODS

2.1 Bannockburn landscape example

In the course of a recent (2004) landscape study, contracted by the Department of Conservation's Research Development and Improvement Division (RDID), Peter Petchey used older conventional photography to map the full extent of the Bannockburn (and Carricktown) landscapes (5). The photograph run was taken 7 March 1958 and is of small to medium original scale (1:16,500, the scale on the negative) sufficient to reveal much essential detail such as sluice faces, dam banks, mullock heaps and major races (Fig. 1). However, at this scale it is difficult to detect small features with low contrast such as the eroded bases of sod walls.

2.2 My aerial photographic methods

I have used medium format film cameras to take low level (below 3,000 feet) oblique photographs, occasionally vertical, and lately the digital equivalent of

35 mm SLR photographs. Because of the cost and lack of flexibility (printing, scanning) of film, I have reluctantly given away film.

Figure 1. *Bannockburn NZAM vertical 2693/12 7 March 1958 at approximately original scale. Stewart Town is just left of centre.*

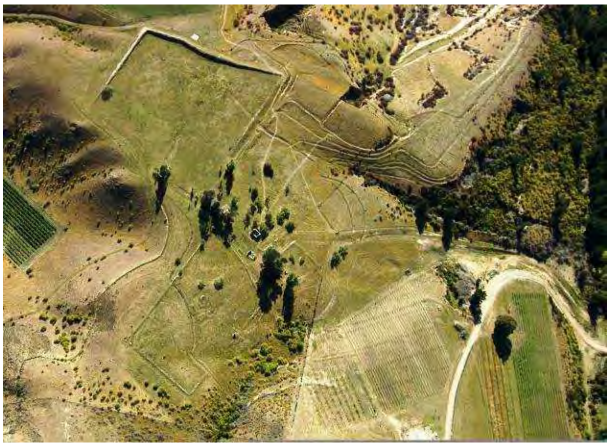

Figure 2. *Near vertical oblique of Stewart Town (compare Fig. 1).*

Taking aerial photographs with the lens oriented at about 45 degrees below the horizontal exploits the many advantages of the elevated view. At the same time a fairly conventional view of the elevations of buildings is achieved. I also find that I can take, especially with the 35mm camera, wide angle views that scan from below the aerial viewpoint and up to the horizon, i.e. there is a low-angle (near vertical) oblique in the foreground, effectively looking down at the subject, but it is framed in a setting which recedes to the surrounding hills and the horizon. This type of photograph provides much needed context for particular sites and fits well with the landscape approach.

If the subject warrants it, instead of making a broad circuit around the subject and pointing the camera at about 45 degrees, I fly straight above the subject, keeping an eye on it as it approaches. Once above the site, I instruct the pilot to make a steep bank and I can point the camera more or less vertically on to the subject. This gives a good plan view similar to that achieved in a map. It allows instant recognition of the pattern of features on the ground but is not so good at revealing the setting, or how the setting might feel if visited on the ground.

The original scale of the photographs is between 1:3,000 and 1:15,000 and allows for the observation and mapping of good detail. This and the subject matter mean that I have tailored a niche that conventional aerial photography does not cover, e.g. in the area of Menzies Dam and Stewart Town, Bannockburn (Fig. 2). Many other examples can be found in my two books (6, 7).

3. GOLDMINING, DAMS AND EARLY FARMING ON THE SHOTOVER

I have photographed the Shotover on a number of occasions using both oblique and medium format vertical aerial photography (Appendix A). Gold was discovered there in November 1862 both alluvial, and later, the major source lodes in the Mt Aurum area (3). By the 1890s it had settled to a steady pattern of terrace exploitation using California sluice monitors and becoming steadily more capital intensive with larger dams and investment in races. The area was abandoned during WW I and re-worked in the 1930s using dredges with large investments in river diversion through cuts in the river bed (Sandhill Cut) and through elevated sheet-metal fluming (at Maori Point).

In 2003 I took systematic medium format coverage of all areas with alluvial mining and in 2006 I led a small Department of Conservation team to make ground records and to observe controls using Geographic Positioning System (GPS) grid points on pinpoint features that could be seen in the aerial photographs such as the intersection of races or the tops of fence posts. I was also able to record and calculate the depths and area of dams/reservoirs, the section and gradient of supply and head races and the nature of the small miners' settlements that are associated with the fields. Following the fieldwork I mapped to scale all the alluvial areas in detail. The results were reported in Jones (8).

The volume of dams fell into two intuitive classes: small less than 1500 m^3 and medium 5,000 – 15,000 m^3 (Fig. 3). The small dams are scattered throughout the Shotover and represent earlier efforts by small teams of informally organised men. The medium dams were company dams built on the large heavily exploited terraces below the Skippers Creek which rises in the main lode areas at Mt Aurum. All dams and head races were informal affairs, did not comply with the guidance in Gordon's (9) *Mining and Engineering; and Miners' Guide* and the dams were much smaller than the late nineteenth-century government dams described by Offer (10) in his *Walls for Water: Pioneer Dam Building in New Zealand*. For point of comparison with Offer, the total volume of the 60 or so dams on the upper and middle Shotover was 94,000 m^3.

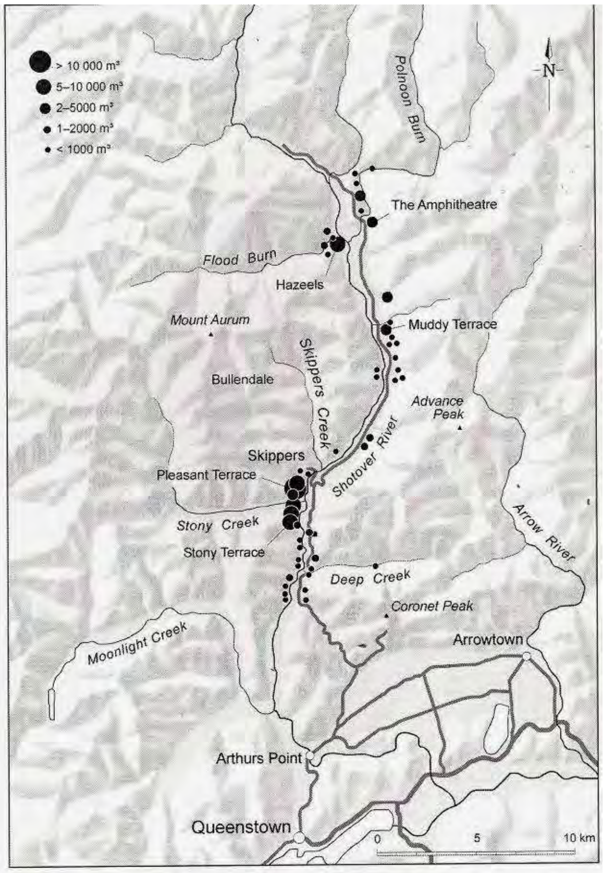

Figure 3. *Volume of dams on the Shotover. Courtesy New Zealand Journal of Archaeology.*

The gradients of head races were seriously steeper and at variance with the gradients of 16 feet per mile (1:300) recommended by Gordon. Again, I suggest that what we are seeing for the most part are early (pre-1880) informally engineered investments that were dictated by the need to get water to the sluice face with the least possible short-term effort. Gordon's recommendations apply to carefully engineered and costly supply races from a later, more capital-intensive period after 1880.

Finally, most of the large areas of alluvial mining were associated with small settlements marked by sod house ruins and ditch and bank enclosures. The enclosures were to keep stock out and to provide yards and gardens for the miners. The largest was just over the proverbial one acre of the miner's right, most were smaller because they had to fit on narrow terraces. This suggests that the earliest miners (1862-1880) brought in horses and their own stock of sheep. It also suggests that there would be conflict with pastoral licence holders in the valley, not simply because of the stock but because of the miners' lawful right to cut races and to fill valleys and river courses with waste gravel.

I found only one site that seemed to be solely of pastoral licensee origin. This was at The Neck between the Polnoon and the Shiel Burn where there is a ditch and bank fence some 120 m long across the high ground between the two streams (Fig. 4). The fence will date to the period before the 1880s (when galavanised wire came into use). In autumn it would have held the sheep up in the high tussock country of Snowy Peak, to be let back down to the easy 'lowland' pastures of The Island just before the snows came.

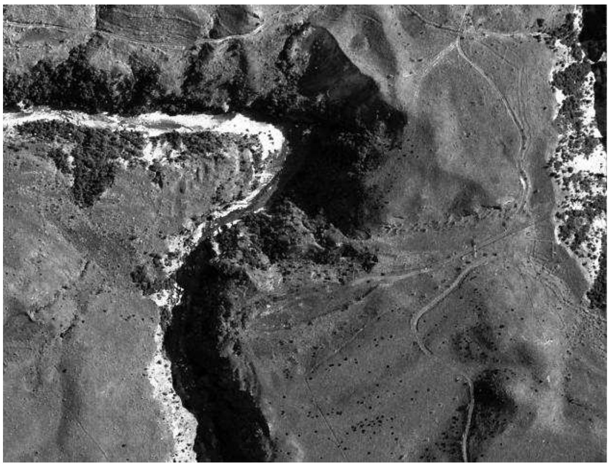

Figure 4. *The Neck, Polnoon at left, Shiel Burn right. The ditch and bank fence runs across the narrowest point at top. The tunnel runs from the prominent bend at top centre to the bright area of water at right.*

Here are some further impressions of my aerial photographic observations on the Shotover.

The remarkable features of Muddy Terrace were in a yellow brown tussock cover with the dams and races defined by the shadows of the afternoon light (Fig. 5). Here and there were sporadic traces of races, dams and sluiced terrace edges. The actual amount of mining seemed low, compared with the extent and invasiveness of the mining further down the river by Skippers. Perhaps these terraces, upstream from what is regarded today as the main lode areas such as Bullendale, had little to offer the miners. Certainly they were not as heavily exploited as the terraces below Skippers.

The downstream end of the Polnoon Burn, above its confluence with the Shotover, is perched above the main valley. About 4 km up it was diverted through a tunnel into the nearby Shiel Burn which allowed the lower part of the Polnoon to be exploited for gold (see Fig. 4 above). I was able to photograph the stream of water which flows with some force out of the tunnel and down a rocky slope into the burn.

Figure 5. *Medium format vertical of Muddy Terrace, dams at centre and bottom (total volume 5,200m^3), sluice faces and the Shotover River at top.*

Below Skippers township and the bridge, the terraces have been very heavily exploited by sluicing with California sluice monitors. As much as half to two

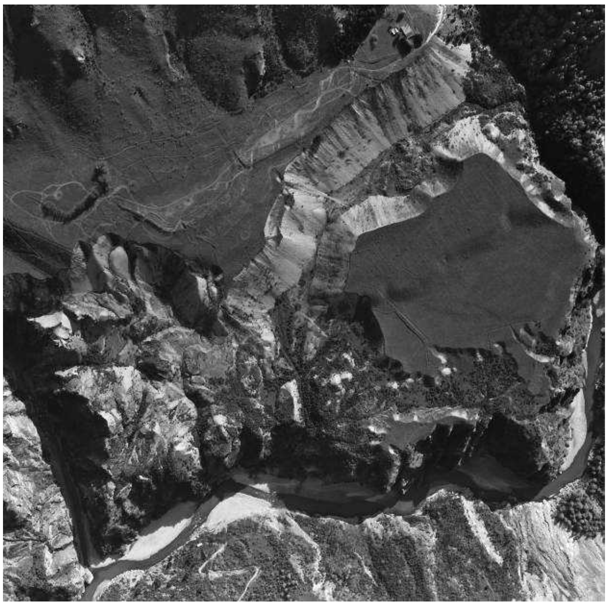

Figure 6. *Medium format vertical of Pleasant Terrace, Shotover at bottom.*

thirds the volume of some blocks of terrace has been removed as at Pleasant Terrace (Fig. 6). The terrace remnants have shallow dams fed by supply races. In some cases the races have entered the main valley by crossing cliffs where only fragmentary wooden supports and light gauge steel pipes remain of the fluming and pipes which carried the water the final few hundred metres to the dam.

4. ENGINEERING SUBJECTS IN OTAGO, SOME EXAMPLES

4.1 The Waianakarua bridges

About 10 minutes flying to the south of Oamaru are the branches of the Wainakarua River and the SH 1 and rail crossing. The river is in two courses. The southern Waianakaru bridge was completed in 1869 and the northern in 1874. Built in Oamaru limestone, the engineer was J.T. Thomson (from 1876 the Surveyor General). They are the oldest bridges on S.H. 1 and have very elegant flat arches in elevation (side view) while the northern one is skewed from the line of the river and has a distinct humpback profile, well captured in an aerial photograph (Fig. 7).

Figure 7. *The northern Waianakarua bridge.*

The southern one was widened in 1962, losing the parapets (11), and giving it a modern form superstructure, driven by the demands of the roadway. This wonderful pair of bridges later had further modifications with the re-alignment of the approaches to the northern one. It was was widened symmetrically with a new concrete superstructure, then the stone parapets (damaged by trucks) reconstructed on the deck cantilevers (Jill Hamel, Lloyd Smith pers. comm.). The aerial photograph shows the relationship with the corresponding rail bridge crossing about 20 metres downstream.

4.2 The Waitaki Dam (1936)

The dam became fully operational in 1936 (*New Zealand Historical Atlas*, plate 88). The dam does not have a conventional spillway gate and over-flow race. Instead surplus water flows over the long (more than 500 m) curved sill which forms the full length of the dam (Fig. 8). The power house on the southern flank is a well known piece of late Art Deco but the curve of the face of the dam and the thickness of it seeming to vanish as it reaches the level of the lake seems to be both elegantly Deco and miraculous in its engineering.

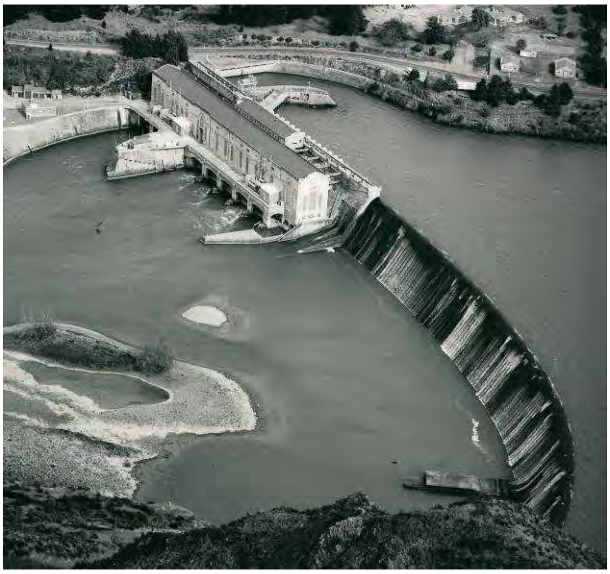

Figure 8. *The Waitaki Dam (1936).*

The broad-footed gorge across which the dam is built seems to be one of those areas where wind and turbulence concentrate. There was an irregular tilting of the aeroplane as we tracked over the hills to photograph the dam. At lake level 2000 feet below, every now and then a small gust would stop and then lift the water trickling over the sill, raising a sheet of spray and blowing it back into the lake.

4.3 The Mt Buster Diggings

The Mount Buster diggings are on a basement of old quartz sand (geologically an old lake bed), as are the deposits in the Nevis valley, the Pisa Range, the Manuherikia valley, at St Bathans and at Kyeburn (3, 11).

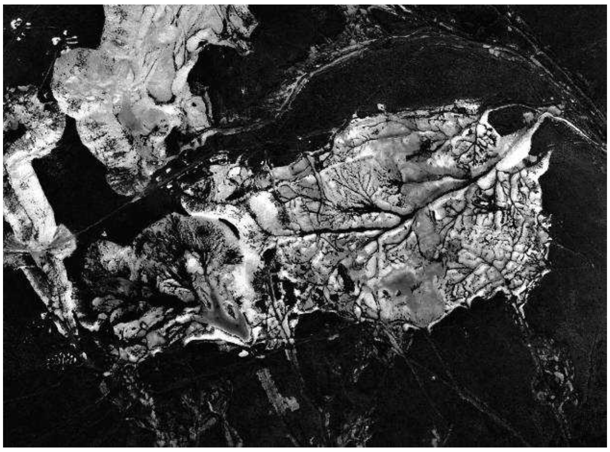

Figure 9. *The Buster Diggings.*

The miners removed the topsoil and overburden to get at the gold-bearing deposits, the base of the deposit presents the white or greyish-white surface of the quartz sand. On Mount Buster or Clarkes Diggings, the oval area of quartz sand left after the sluicing are seamed by the dendritic (branch-like) form of the tail races (Fig. 9). Filled with peat, they stood out in a dark colour, each of the sluiced areas like a section of a kidney with the veins showing. Tiers of dams, filled with a slow accumulation of peat, occupy shallow gullies above the sluiced areas. Races lead from them to the work face but the relief of the land is difficult to determine in the flat light from the overcast sky.

4.4 Golden Point Historic Reserve and Macraes open cast

The modern Macraes opencast mine has worked out the general area of the old adits and drives on the lodes which fed the batteries at Golden Point, now an Historic Reserve. From 1888-89 through to 1944, the miners exploited the main economic lodes here (12), conducting deep, branching drives at many levels into the reefs. Golden Point Historic Reserve itself is an important assemblage of batteries, other buildings, hut terraces, and a series of dams from which water was taken via races to drive the battery and to exploit the small area of alluvial gold on the narrow valley floor (Fig. 10).

Figure 10. *Golden Point Historic Reserve. Callery's Battery at centre, old mullock, adit entries and the boundary of the Macraes open cast at top right.*

From the air, the significance of the reserve may seem reduced by the area of the opencast, but they both reflect the same economic imperative – gold extraction – and the one is partly the reflection of the other. But the technology has changed along with community attitudes.

4.5 The Criffel Range diggings

These were a cluster of short-lived, high-altitude (1300 m a.s.l.) fields that had a continuing shortage of water. At its peak (1880s) it was served by a series of very long races (some 15 km long) from the upper reaches of the Luggate Creek and a pack track from the Wanaka area. I mapped this field from 35 mm format positive film (slides) at original scales of 1:18,000 enlarged for mapping to scales between 1:2,800 and 1:5,000 (see Fig. 11).

In this challenging environment, a lot of effort was put into exploratory shafts and into securing a supply of water that was suitable for only a short summer season of effort. The water races as recorded are in fact three narrow benches on which pipes probably of a thin gauge of steel were laid.

Figure 11. *Medium format vertical of Western Criffel Diggings showing pipe route top left and exploratory shafts top right.*

5. CONCLUSIONS

In this paper I have reviewed the value of older vertical aerial photography for historical analysis. It is critical that these resources are retained and kept well curated for use at the National Archives, Wellington. The current circumstances of aerial photography in New Zealand are that national programmes are weak (for the large scales needed for archaeological work) and there are many niche areas of aerial and remote sensing all looking for a market. My own practice is large-scale (low-level, below 3,000 feet) oblique and vertical aerial photographs of sites, structures and buildings, using the advantage of the aerial view: identification, analysis of pattern and persuasive imagery for advocacy of heritage. These methods all have application to the remarkable heritage of engineering in Otago.

6. ACKNOWLEDGMENTS

The conventional New Zealand Aerial Mapping vertical photographs are Crown copyright. My photographs were taken in the course of employment by the Department of Conservation. My original paper on the Shotover was published in the *New Zealand Journal of Archaeology*. Parts of this paper were developed in the course of seminars on 'Writing the Land' at the International Institute of Modern Letters, Victoria University of Wellington. I thank Dr Jill Hamel for comments on the draft.

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8. APPENDIX A

Aerial photographic flights carried out in Otago. Negatives and originals are held at the Head Office Department of Conservation and should be accessed through kljarchaeologist@paradise.net.nz. A search fee is charged. National coverage is listed at: http://www.nzarchaeology. org/elecpublications/aeria l%20photo%20 index%202.htm

Sites covered	Date
Kawarau, Cromwell, Northburn, Bendigo, Arrowtown, Chinatown	Aug 1991
Earnslceugh, Kawarau Gorge, Macetown, Branches Station, Shotover River, Skippers, Moonlight Creek	5 Sept 1995
Macetown, Heyes Creek, Branches, Mt Aurum Station (verticals with 35 mm camera)	23 June 1996
Gibbston, Coalpit Saddle, Nevis, Alexandra, Manuherikia R, Otago Central Railway (Raggedy Range), Poolburn Viaduct, Cambrians, Bendigo, Kawarau Goldmining Centre/Gees Flat	24 July 1997
Arrow River (verticals), Macetown, Brackens gully, Heyes Creek, Soho Homestead, Rich Burn, North Branch Arrow, Scanlans Gully, Sylvia Creek, Advance Peak	24 May 1999
Cargill’s Castle, Donaghy’s ropeworks, Larnach’s Castle, peninsula fields, Quarantine Island, Carey’s Bay hulks, Otakou umu ti, Harrington Pt, Taiaroa Head, Long Beach, Mapoutahi, Seacliff rail cuttings, Puketeraki, Huriawa, Cornish Pt, Matanaka buildings, Pleasant River, Shag River, Katiki Point, Moeraki wharf, Dunback lime quarry, Macraes, Golden Point, Murphy’s Flat, Nenthorn, the Great Sod Fence, Barewood, Lake Mahinarangi, OPQ Battery, Gabriel’s Gully, Blue Spur	22 July 1999
Timaru, Waitaki River mouth, Pukeuri, St Kevin’s College, Waitaki Boy’s High School, Railway Station, Catholic Cathedral, Masonic Hall, Whitestone area/Harbour and Tyne St, Waitaki District Council Chambers, banks, gardens, Cape Wanbrow, Kaka Point, Totara Estate, Waianakarua bridges, Shag Valley Station, Golden Point, Deepdell Station, Longburn, Kyeburn, Mt Buster, Otekaike	18 April 2002
Timaru, Waitaki River panoramas, Maerewhenua, Waitaki Dam, Otekaike, Mt Buster diggings, Kyeburn diggings, Longburn Station, Taeri Lakes Station, Cottesbrook Station Garthmyl Station, “Stonehenge” on the Rock and Pillar Range, Puketoi Station, Taieri meander belt, Rough Range, North Rough Range, Oturehua, silcrete quarry, Hayes Engineering Works, Blackstone Hill Station, St Bathans, Blue Lake, ‘Grey’ Lake, Lauder Creek and Thomsons Creek goldmining, Bendigo, Kawarau Gorge, Roaring Meg hydroelectricity station, Kawarau suspension bridge.	21 April 2002
Olveston, Royal Tce, Botanical Gardens, Knox Church, Otago Museum, Benhar, township, Hoffman Kiln, industry Milton, limestone quarry near Milton, Taieri Mouth, Taieri Island, Brighton, Clutha mouth, Watson's Beach, Myre's Homestead, Balclutha rail bridge, Balclutha road bridge, chicory kiln, Waitepeka, Telford Inst, Clutha mouth, The Glen, Romahapa, flax mill, mill pond, Nuggets, Lighthouse, Pt Molyneux cemetery, Murikauhaka, Port Molyneux township, Wharf shed, Flax mill (Flax Mill Road), Dunedin Southern Cemetery, Otago University quadrangle, Northern Cemetery, Botanical Gardens, Octagon, St Clair, Black Head, Otago Boys HS, Otago Polytech, Railway Station, Dominican Priory, First Church, Octagon, Quarantine Island, Goat Is, Scott Memorial, hulks (Carey's Bay), Victoria Channel, Harbour Basin, Port Chalmers.	3 July 2002

3rd Australasian Engineering Heritage Conference 2009

Engineering Archive - Preservation and Prospects.

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In Memoriam: BRUCE R. GAMBLE: 1942 -2004.

***SUMMARY**: Strategies for collecting, conserving, discussing and making available Engineering Archive are reviewed. Because the field for collecting is so wide, categories need to be identified. The category of books and papers, such as letters, plans, and similar, is a primary interest here. The internet has to some extent replaced conventional books and papers for everyday use and reference. In archival terms this has strengthened the case for wishing and needing to value and conserve the books and papers from the pre-internet era. This need will continue into the future even if the on-line coverage and content continues to expand in unexpected ways. Educational initiatives are also discussed for promoting the preservation of engineering heritage. These initiatives could also complement the aims of the IPENZ Foundation in the future.*

Keywords: Biographical archive, educational opportunities, engineering archive, personal archive, provenance, public domain.

1. INTRODUCTION.

This paper can be regarded as a sequel to an earlier paper, [**1**], presented in Dunedin at the IPENZ annual conference twenty years ago. We shall adopt a definition for 'engineering archive' as being: essentially any materials, be they hard copy or electronic, which relate to engineering in the broadest sense. This is potentially a very wide spectrum of materials. What is in practice collected will depend upon availability and the scope to provide secure storage and preservation regimes. Clearly in practice there is a very severe limit on storage and preservation facilities. There are also selection criteria to be agreed upon. And this is in an ideal world in which there is access to potentially important material. Framing a comprehensive policy for collection of heritage material is not a well defined task. There is considerable scope for preferences to be expressed. The priority material of most interest to this writer is biographical archive. This is a small subgroup of the whole field. A special feature of this type of archive is that much of the most interesting and relevant material may be held privately. Then arises the question of how the material is identified as existing, then how it might be assessed and, if thought to be of sufficient importance, how to acquire the material for a collection associated with the profession, to be held by the Institution, or in a public library or other accessible venue.

The companion paper,[**1**], was written at a time when major changes and upheavals were occurring in our countries and in particular, in the employment regimes for engineers. Government owned entities, such as the Ministry of Works in New Zealand, and other similar repositories of engineering expertise, were being privatized. The rapid change saw much engineering archive changing hands, sections of it passing out of the public domain and some just being destroyed! In the last twenty years there has also been the ever growing mass of on-line archive materials. Most of the discussion here will refer to New Zealand conditions, with some references to Australia when the author feels comfortable to make them. First we shall review outcomes from some of the earlier changes, before going on to discuss the future for engineering archive in the current social and economic environment. We also venture some discussion of what amount to policy matters. This is an attempt at bringing the heritage topics in a general way into the mainstream teaching environment of the B.E. degree. There is potential to ally cultural and technical considerations in a more integrated manner. A future best-case scenario could be a profession better informed on cultural and technical issues, and the interplay between them.

2. RESUME OF THE 1980'S CHANGES.

Paper [**1**] drew attention to the likely fate of important publicly owned engineering archive. Some important documentary collections, such as those within the then MOW, have been lost to the public domain. The Copyright Act, as an agency in archive collection growth, was also discussed in [**1**]. Since then the Act has been revised. The changes made were largely driven by the publishers and the trade and not the community at large. As a result, New Zealand is out of step, and behind, in the application of Deposit Rules for publications, and the role that such rules play in collection formation and growth. Other unanticipated changes and disposals have also occurred - for example a significant disposal of technological materials was made by the Royal Society of New Zealand from their library in the late 1980's. Details of the materials culled from their collection are not on the public record but some of the disposals can be reconstructed from the various items that appeared on the market at the time. A typical example of a disposal is the book, '*A Treatise on Natural Philosophy*', Part 1, by W. Thomson (later Lord Kelvin) and P.G.Tait,Oxford,1867. The title '... *Natural Philosophy*' reflects the circumstance that both authors were Scottish academics. This book was one of the most influential and valuable works on mechanics in English in the nineteenth century. The copy disposed of was a first printing and of special interest as a result. It may have been unique in the NZ library system. In addition to the Thomson and Tait, several other scientific classics and early New Zealand items were disposed of. One such classic was a first edition of J. Clerk Maxwell's '*Electricity and Magnetism*' of 1873. This work is of comparable importance to a first edition of

Newton's 'Principia..' of 1687. A NZ item sold at the same time from the Royal Society Library was the Hockstetter Atlas of 1864. This includes detailed maps of the Pink and White Terraces before their destruction in the Tarawera Eruption. We shall return to the library sphere and collection policies later.

One emphasis here will be on biographical and especially personal archive. It was observed in the 1989 paper,[**1**], that this is probably one of the most vulnerable forms of archive in our social fabric, and not just in the engineering sphere. Sometimes important archive may be safely housed in a public domain location, possibly during the owner's lifetime. But at least as often, this is not the case, and the fate of the material is probably decided by family members who are only vaguely aware of the potential importance of the materials. Combine this with the other pressures and duties falling to the family members at the time of a parent's death and it is not hard to visualize the scope for important materials to be lost.

In both Australia and New Zealand several very valuable public domain library collections have been received as bequests. In several cases these important, personally assembled, collections have become essentially the core collections of State and National libraries. Their emphases differ according to the particular interests of the donors but in general they embrace a wide range of subjects. Many of the great libraries around the world have benefitted, and continue to do so, from the copyright provisions of the particular country. This was a point brought up in the earlier paper[**1**]. New Zealand lags in this regard. General cultural materials usually form the core of these collections. Most have very limited holdings of engineering or technology materials. The importance of these early collections cannot be over estimated due to their deposit in the public domain. In Dunedin there is the Hocken collection. Other nationally important New Zealand collections are the Turnbull collection, which forms the core of the research library within the National Library in Wellington, and the Grey collection in the Auckland Public Library. It is relevant to note that Grey, during a long and varied lifetime, corresponded with several of his contemporaries, several of whom were pioneers in the sciences and technology. As a result there are what are now especially valuable copies of his correspondents' works to be found in the Grey collection. In Australia there are world class collections such as the Mitchell and Dixson in Sydney, and others interstate.

To conclude on the 1980's changes, undoubtedly much in engineering archive terms has passed out of the public domain, and this must be regretted. How much of potential longer term importance has actually been *destroyed* as the result of the changes at that time it is probably impossible to estimate in any sort of useful manner. Library deposit is likely to feature prominently in any future active archive collection policy by the engineering profession. The location and resources available for secure, long-term preservation become important. National libraries, and official Archives, no doubt have a role to perform for housing some categories of engineering archive. In the present circumstances engineering and technology archives are not priority materials in national collection development terms. The profession therefore needs to have a policy and proceed to collect according to that policy. Part of any policy must include housing a collection and identifying resources to maintain it.

There are exceptions to most rules and this is true for some national Library collections and their hunger for particular engineering archive. In the case of Sydney two high profile engineering feats are enduring subjects of interest to libraries and librarians - namely the Opera House and the Bridge. The Opera House and the constant references to its past and present ensure continued public interest. The Bridge runs a close second.

3. THE PRESENT SITUATION.

There has been a long held view in the profession that engineers and engineering are undervalued in society at large. We engineers, among the professions, are not alone in holding such a view of our profession. Archive of importance in some general sense is in a tenuous way linked to personal and collective prestige and acceptance in society. Engineers and engineering are largely creations of the Industrial Revolution. Paradoxically the case could be made that an emerging profession is best able to catch the public imagination in the early rather than the later, mature years of the process. For the Western world, and especially the English speaking world, the mid nineteenth century was the high point for the engineer and engineering being at the forefront of public awareness. The Scottish medic-turned-author, Samuel Smiles (1812-1904), published the first of his volumes of the 'Lives of the Engineers' in 1857. Eventually five volumes were produced. These were popular works and remained in print for half a century. Indeed they remain in print in an abridged form.

Smiles was an observer of social issues. His lifetime spanned the period of rapid and often very difficult social changes, brought about by the very rapid changes associated with industrialization. Engineers played a civilizing role in these changes in Smiles' view. We would probably all agree with him, and then go on to expect the role for the engineer might be seen as the same today. But this does not appear to be the case, at least not in the public perception. Why is this so, if it is so? Darwin published his great 'On the Origin of Species' in 1859, as we are currently being reminded. He shared the same publisher as Smiles, John Murray, whose publishing house went on to become a dominant science and technology publisher. Darwin's influence has taken many twists and turns to get to the present pre-eminent position. His work was far less read at the time than were the Smiles books. Darwin's is an easily recognizable name in modern society, but few engineers, if any, are in the same league! An exception might be Brunel: perhaps paradoxically, Smiles did not include him in his 'Lives..' volumes. Has our day passed for recognition? Personally, I don't think it has. On the other hand there are some missing elements in the recognition picture. Paucity of engineering-related archives, in a general sense, is one of the missing elements!

Often the most highly regarded of history texts can be searched in vain for references to engineers as individuals, whereas politicians and others of the time are named and their activities are described in the unfolding history. There are no doubt many reasons for this circumstance. If the event being referred to is being written about by an observer such as an historian, then the probability is that many sources are referred to prior to the account being written. In broad terms the engineers are frequently not identified even though the products of their expertise are the subject of the writing. Some of the reasons for this omission are that the primary records from which other compilations are made are not specific about the personnel who created the original infrastructure. This anonymity aspect may then be layered with other relevant records and has contributed to the engineer's low profile. One remedy would be to better document authorship. This should then lead to a situation where personal archive becomes easier to accumulate, and only then can it be preserved, if this is the decision later. It would be interesting to know, for example, how many of us attending this conference are regular keepers of a personal diary! This is the most individual form of personal archive and is the basis of much of the most reliable knowledge about individuals in historical terms. Taking the argument in a slightly different direction, it could be argued that diary keeping should be urged upon the young engineer as an important professional as well as a personal discipline. Whatever our personal inclinations and habits, it is a matter of observation that reliable biographical information, for engineers as a social group, is often difficult to obtain. This brings us to consider how others view us as a profession, and what we can learn from this.

4. ENGINEERING ARCHIVE - BIOGRAPHICAL.

For present purposes '*Engineering Archive*' is being regarded as any aspect of an engineering structure or end product. This leaves us with all facets of planning, design, construction and operation, and very importantly, archive relating to the personnel involved. Elsewhere [**2**] the national collections of biographical archive are discussed. The nearest to home for us are the Australian Dictionary of Biography (ADB) and the Dictionary of New Zealand Biography (DNZB). Both these publications are modeled in many respects on the UK Dictionary of National Biography (DNB). The original DNB was a 60 + volume work. It was first published in the last quarter of the nineteenth century, from 1885 till 1900. Several supplements were issued subsequently. This was a mammoth task. The key editor of the DNB was the literary figure, Leslie Stephen, Virginia Woolf's father.

Over the last twenty years this whole corpus of biographical information has been reviewed and was recently greatly expanded and brought up to date. The new version is now known as the Oxford Dictionary of National Biography, the ODNB. There is both a print and an on-line version. There is also a policy of regular, continual, ongoing updating. Apart from the individual's merit to be included in the dictionary, as perceived by the dictionary editor(s) of the time, the key editorial policy common to all three dictionaries is that the individual to be included must be dead! All three publications adopt the format that all essays are signed by their authors. The source materials used to write an essay, or revise in the case of the ODNB, form part of the essay.

There are significant differences in editorial policy evident across these three prestigious publications. The ODNB and ADB include more personal archive on their subjects, for example their probate details, than does the DNZB. On the other hand the DNZB has a much more liberal policy in the choice of subjects - more the 'worthy', and even 'notorious', rather than 'celebrity' subjects have featured in DNZB than in ODNB and ADB. But when it comes to looking at the results of these various editorial policies it seems that engineers along with some other professional groups are more sparingly represented in the DNZB than in either of the other dictionaries. (One entry in the ADB that does not appear to follow the 'rules' is the essay on Azaria Chamberlain - the nine-week old baby who disappeared in the outback in 1980.)

Similar observations to the above have been made elsewhere [**2**], and some reasons have been advanced for the differences. Unfortunately, the single most canvassed reason for the paucity of engineers in the DNZB is said to be because there is too little, reliable biographical data available for a suitable essay to be written on the individual. This situation has improved in recent years. There have been initiatives taken to accumulate bio-data, including taped interviews, from Institution members during their lifetimes. How this data will be disseminated is still under discussion. The manner in which Privacy Laws are administered may also make it more difficult in the future to trace the careers of individuals.

These differences in editorial policy have led to a situation, at least where engineers and technical people are concerned, where if the individual has pursued a career outside of their birth country there is little prospect of their being included in the DNZB. Contrast this with ADB policy, as seen from the resulting volumes, where even if an individual spent only a brief time in Australia but has caught the eye of an editor, they have been included in the ADB. Two examples illustrate the point - William Hudson and Clifford Dalton. Both were NZ born, neither is included in the DNZB. Both are included in the ADB. In Dalton's case he resided in Australia for only a few years. The reason for his inclusion is no doubt because of the key postings he held in that brief time. Sir William Hudson's inclusion is no surprise, given his many years of service in his adopted country and the distinguished contribution he made. Other examples of expatriates in related fields to engineering who have been passed over by the DNZB are Leslie Comrie, a pioneer numerical analyst of world standing in the emerging field of large scale computing and what has evolved into IT, and Alexander Aitken, a very distinguished mathematician. The ADB on the other hand has lengthy essays on many expatriates, for example Howard Florey, whose careers were spent entirely outside of Australia. With a cap on available space in works of this kind it is not surprising that some worthy individuals are not included. This is especially true of the DNZB since there is no policy in place to up-date or extend the set of five volumes which were published during the 1990's. The ADB currently runs to about seventeen volumes, with others in active preparation.

Another publication we need to refer to in the present context is the *New Zealand National Bibliography (NZNB)*. This five volume work, bound as six books (Volume One extends to two Parts in two volumes) was designed to gather together all relevant bibliographical information on New Zealand publications. As can be imagined, such an enterprise was a huge task. The Editor and Principal Compiler for all the volumes was A. G.(Graham) Bagnall (1912 - 1986). He was probably the most distinguished NZ bibliographer of his time. During the years of compilation of the NZNB Bagnall was the Turnbull Librarian in the National Library, Wellington. This amounts to his being the chief research librarian. The brief was to cover the period from the earliest times until 1960. The whole period was divided into two sub-periods: earliest times till 1889, then 1890 to 1960. The first volume was published in 1969, being Vol.2 covering A-H of the period 1890-1960. Then followed Vol.3 I-O in 1974 and Vol.4 P-Z in 1975. Volume 1 (in two books) followed in 1980, and the series was completed with Vol.5, Supplement and Index, in 1985. The Editor was by then more than ten years into retirement. He died the following year.

When we refer to these volumes today, the erudition of the compilers' is very evident. The series is an extremely valuable national resource. This is not to say, however, that it does not have areas of omission. This writer cannot comment on the completeness of the coverage for the literature and social sciences and arts generally. But the work clearly does not pretend to cover engineering and technology in any comprehensive way. On the face of it this seems somewhat paradoxical. Some areas of technology are apparently covered in some detail. These are mostly related to farming practices, and the supporting sciences such as botany.

There are some non-literary categories that feature: for example, mathematics. D.M.Y. Somerville (1879-1934) and H.G.Forder(1889-1981), both distinguished academics who occupied the mathematics chairs at Victoria and Auckland University Colleges for decades. Their several publications, including some published before they arrived in NZ, are listed. But several other mathematician's works are not. Recall, too, that importance is not a criterion for inclusion. The physicist Ernest (Lord) Rutherford's books are listed, but the Dunedin alumnus, Joseph Mellor's more numerous and very distinguished chemistry volumes are not. Let us consider engineers, NZ by birth and/or working in the country, and publishing. Mining engineer James Park's texts are listed, but A.M. Hamilton's papers on his WW2 bridging system are not, even though they fall well within the time period. Hamilton's book about his experiences as an engineer in Iraqi Kurdistan between the wars is listed, but without a reference number, possibly indicating it was a last minute addition. Of more importance for engineers in the future, who might expect to obtain some guidance from the NZNB, there is no reference to the *Proceedings* of the NZ Society of Civil Engineers, as the Institution was titled until 1939, and where many valuable technical papers were published. Even given the exclusion of periodicals it seems odd that no reference to the content of the volumes is made. These pleasant to handle, quarto-size volumes contain a unique archive of close to forty years of engineering endeavour in NZ. Current IPENZ publications policy is not producing comparable technically competent papers and descriptions of works as was achieved by the *Proceedings* in the period 1914 to 1951. By 1951 '*NZ Engineering*' had become established as the Profession's publication vehicle, despite the private ownership structure that had been adopted. In its turn, *NZE* proved to be a worthy publication and itself is the primary reference for all matters relating to the professional engineering of the day. The change of ownership and format in the 1990's and the later change of format for Annual Conference and publication of their technical programme and papers, has greatly weakened the chain of creation of contemporary NZ engineering technical archive. Because of the vicissitudes of the engineering library holdings in NZ over the years it is possible that there are fewer than possibly three or four complete runs of the *Proceedings* volumes on any shelves, anywhere. This makes them an endangered species! Given this scarcity, a useful project would be to summarise the contents under a variety of headings and draw attention to the excellent and important papers by authors, such as Arthur Mead, and the city water supply and environmental conservation work that he and others largely pioneered.

To illustrate the fragility of the engineering bibliographic content in the NZNB consider the entry for S. I. Crookes in Vol.2., covering items C1787- C1791. Crookes' dates are given as 1871-1955. These describe electrical engineer Samuel Irwin Crookes, **senior**. He was President of the NZ Soc. Civil Eng. in the year they decided to embrace all engineers, not just Civil in the name, and became NZIE, in 1938-9. None of the references quoted are by this Crookes. Apart from a 4p report (C1788) based on data supplied by this Crookes, all the other items were written by his son, S.I. Crookes,**Junior**(1896-1983),[**2**], who was a structural engineering academic and an almost forgotten pioneer in the field of earthquake engineering. There is no reference to SIC Jnr. in the NZNB or any of the other biographical collections referred to above.

From what has been described here, and elsewhere in this paper, there is clearly ample scope to map out plans to fill the many gaps that there are in the public record so far as the profession and the professionals are concerned. One possible reason for the lack of inclusion of any mention of the *Proceedings* in the NZNB is that the unenthusiastic remarks Newnham makes about the quality of the early *Proceedings* in LSA(see below), at p.336 for example, were read by, or known to, Graham Bagnall when he was working on the compiling of the NZNB. Indeed it would be interesting to know whether the two men were known to one another. One future scenario could be to prepare what amounts to the copy needed to fill the major gaps that the engineering profession might see in the NZNB as it relates to engineering and technology publications. The worst case outcome of this would be if the National Library took no interest in the material. A next step then might be for the Institution to incorporate these bibliographical materials into a centennial history of the Institution, sometime on or after 2014.

The accessible biographical archive relating to engineers working in NZ during the early period of European settlement is almost entirely confined to the pages of F. W. Furkert's (1876-1949) 'Early NZ Engineers'(ENZE),[**3**]. This was published in 1954, some five years after Furkert's death. The circumstances at the time required that the manuscript be further edited before publication. This was undertaken by his successor and colleague, W. L. Newnham (1888-1974). (*WLN shared the same birthday as FWF, and was twelve years younger.*). There are no references provided in ENZE. But there is mention of Furkert's preliminary working manuscript materials, which passed to Newnham. We can presume these would have included references to sources. What appears to be lost are all these preliminary materials on which the book is based. What became of these materials seems to be unknown. It is safe to assume that these papers would have been a valuable archive for any future project to take up where Furkert's biographies terminated, at engineers whose birth year was before 1867.

Another book, which in some respects carries the Furkert work further, is Newnham's 'Learning, Service and Achievement', ('LSA'), [**4**], published by the NZIE in 1971. This was intended as a history of the Institution from the foundation in 1914 as the NZ Society of Civil Engineers until 1964, fifty years on. There is thus a gap between the end of Furkert and the start of Newnham, of about forty years until the First World War. This is a simplification of the comparison. 'LSA' is more a history than a biographical work though it does contain useful biographical notes, including about Furkert. If references to a work are a usefulness indicator, then the impression is that 'LSA' is not much appreciated judging by the sparse references to it. But we would have a much poorer knowledge base of the Institution and engineering in New Zealand if this work had not been commissioned. Ironically, Newnham, after being Furkert's editor, found himself unable to finish the LSA work he had began. Newnham was the editor of a series of commissioned essays though we do not know the authors of any of the component parts. A further editor was appointed and he brought the book to a conclusion and eventual publication, some seven years after the intended date. Fortunately for the profession that second editor was himself both an engineer and a writer/publisher: F. N. (Nigel) Stace (1915-2001), the then editor/owner of the journal, '*NZ Engineering*'. For reasons that Newnham says in his preface were related to the editing role he occupied, he took the decision to delete all the names of the authors of the individual chapters. This seems a drastic step and one that probably cannot now be retraced, since it appears that in this case too, all the preliminary drafts and associated papers have not survived. This is unfortunate and as a policy, hopefully will never be repeated. A sign that there may have been haste to complete the task could account for a mis-spelling in the title on the upper board of the binding. It is likely that Furkert and possibly Newnham made use of the materials contained in the several provincial 'Cyclopedia' volumes that appeared in the late nineteenth century. Valuable they are but a little caution needs to be exercised when using these sources since they were assembled from materials authors submitted to the publisher after paying a fee for inclusion of their material. With the centennial of the Institution in about five years, now would be an appropriate time to consider the scope to write a centennial history!

What is clear is that there is ample scope for further studies of the early engineers who were active in NZ, especially in the period c1880 to 1914. This was when much of the railway expansion was occurring, along with the opening of the North Island Main Trunk rail line, and with continued growth of the towns and cities, roading and other infrastructure. It would be a task not to be entered into lightly, but as a worthwhile venture a companion volume to the Furkert and Newnham books should be facilitated by the profession. A preference would be to have such works, if not wholly written by, at least edited by an engineer. This may be difficult to achieve, especially in the current environment where the NZ Profession's only regular in-house publication, eNZ, is composed of articles commissioned from journalists. A section of the professional membership is retired. Their proportion of the whole membership is likely to grow in the years ahead. There is a case for harnessing their knowledge and writing skills to provide suitable copy, especially in progressing any successor volume to the Furkert and Newnham volumes, or of a centennial history of the Institution. The authors of any published materials should be identified in the same manner as is the editorial policy of all three of the Biographical dictionaries discussed above.

Beginning in 1908, editions of *A Who's Who in New Zealand.*. have been published at irregular intervals. About fourteen editions have been published thus far. The editor for the early editions was G.(Guy) H. Scholefield (1877-1963). A newspaper editor and historian, GHS also wrote the first (two volume) DNZB, Wellington, 1940. The particular virtue of a Who's Who.. is that the biographical information is provided by the subjects themselves, but only at the editor's invitation. In stark contrast to Dictionaries of Biography, the Who'sWho consists exclusively of *living* subjects. There are several very interesting and valuable mini self-portraits of engineers in this now century old publication.

5. ASSOCIATION COPIES.

In addition to archive of the type we are advocating should be sought and preserved in accessible collections, other facets of career and the achievements of engineers can be gleaned from association copies of works of importance, most especially books, known to have been owned and/or used by engineers of the period. These might be copies of documents or books authored by the particular engineer, or more often are likely to be other materials which are known to have been in their possession. How much they may have used such materials is another, and probably unanswerable, question. For example, when we come to ask how a particular engineer may have sought to acquire particular skills, are there available in national collections books and other materials which the individual owned or is known to have studied from? In the 1930's there were developments in structural analysis in the USA, the UK and elsewhere that were capable of supplying reliable numerical results for the actions generated by loads acting on indeterminate frameworks. Earlier there had been developed methods for indeterminate analyses that required equation solution rather than iterative methods of solution, for example the energy theorems of Alberto Castigliano (1847-1884). Whatever the method employed, long before the advent of computers, the humble slide-rule and, if need be, tables of logarithms, were about the only computational aids available. Methods of problem formulation capable of describing the increasing use of rigid concrete frame construction, required new insights and more detailed and powerful methods were being sought. One of these was the Hardy Cross method employing an iterative solution, known as Moment Distribution. Pre-WW2 the Auckland office of the consulting engineers Jones and Adams produced designs for building structures in concrete and may have had need to get abreast of these latest methods. At least the personnel did have access to a copy of Cross's 1932 published book, with Morgan, titled 'Continuous Frames of Reinforced Concrete', because Jones' copy survives. It is signed 'Stanley W. Jones, 1939'. Judging by the condition, it had been referred to on many occasions. American engineers of the period favoured rigid concrete arches for many medium sized bridge structures and Cross devotes considerable space to their analysis. Jones and Adams designed several concrete arch bridges across the Waikato and other sites, especially after WW2.

In the same building, Smiths' Building in Albert Street, Auckland, was the consulting practice of Gray and Gulliver, later to become Gray and Watts after Gulliver's death in c. 1939. Did W.A.(Arthur) Gray (1889-1953),[**2**], decorated , wounded and a Prisoner of War in World War One, who was the main and very able designer in the practice, have need for, or access to, such an aid as the Cross and Morgan book? The iconic Auckland War Memorial Museum, with concrete casings of the structural steel frame and floors, and Portland stone clad facade, was built to the structural designs by Gray. But it had been completed before the appearance of the Cross and Morgan book. In passing it could be noted that Gray's contribution to the project is not acknowledged on the dedicatory plaque on the building, [**2**]. About the time that Gray died, the highly innovative tubular steel space-frame structure for the new Members' stand at the Auckland Racing Club's Ellerslie racecourse was in preliminary stages of design. Gray's partner, and nephew, Lawrence (Larry) B. Watts (1908-1966) was the principal in the practice who saw the project to completion. Watts, a very able designer in the Gray mould, had gained foreign work experience after graduating from Canterbury before WW2. The engineer primarily responsible for the analysis was Harold E. Wallace (c.1907- c.1991), a well qualified Maori engineer, who had been teaching structural analysis at the Auckland School of Engineering at Ardmore, before joining the Gray, Watts and, by then, Beca practice in the mid 1950's. Later he joined the staff of the Architecture School, and remained there until he retired. As it happens, the basic tubular structure for the Ellerslie stand was considered to be determinate, with some allowance made for joint rigidity. So computation, though lengthy and tedious, did not need to draw upon Cross's methods. Nevertheless it would be interesting to establish whether their office had a shelf of books, perhaps including C & M, and which were the most heavily used items! The Jones and Adams partnership evolved into Jones, Adams and Kingston, and then into Kingston, Reynolds, Thom and Allardice. In retirement, Ian Reynolds spent much time and effort researching the history of the practice. This writer has not seen the results of his efforts. They are undoubtedly valuable.

Energy methods played a substantial role in post WW2 structural analysis teaching. The Castigliano energy theorems were about eighty years old at that stage. They became known in the English-speaking world through the translation of Castigliano's 1879 book from the Italian original into English by Ewart S. Andrews, a London-based consulting engineer and academic, in 1919. Andrews was himself the author of several well regarded books, covering structural analysis, strength of materials and reinforced concrete (RC) construction, in the early years of the twentieth century. One of his books on RC construction, published in 1912, and owned by E.J.R.McLaren, an early staff member in the Auckland Engineering Department, survives. This copy is signed but not dated. It is annotated and has been well used.

We are all made different and often value a particular artifact very differently. Personal experience has been that associations of the type described above are not always seen as relevant or of value. When the person making such a judgement is the head librarian in an important library then the scope for advancing the cause of (engineering) archive is made that much more difficult. Such a situation has arisen in the writer's experience. A book collection, part of which could have been of potentially archive quality, was acquired by the particular library. The instruction went out that all ownership marks in the books were to be erased. This goes to the heart of archive collecting practice! Provenance, that is previous history of ownership, can be a vital tool in the study of archive. To have this information obliterated from books (or other materials) given to or acquired by a library is, in this writer's view, a form of vandalism, and a reason for hoping that collections do not fall into hands that do not value the association!

A known association copy of a work of importance is the copy of Rankine's 'A Manual of Civil Engineering, 8th Edition, Glasgow 1872', with ownership documentation extending back to the original owner. On the title page, in a clear hand, is 'E. G. H. Mainwaring, Christchurch, Feb. 1873'. The 8th edition was the last revised by the author. Rankine died on Christmas eve 1872, just months after completing the revision. This important text-book, first published in 1862, remained in print until well into the twentieth century and continued to be revised at regular intervals and long after Rankine's death. Of all the sources of education and instruction available to the young professional engineer, in the period 1858 to 1900 especially, one or more of Rankine's several 'Manuals', on Applied Mechanics (1858), The Steam Engine...(1859), Civil Engineering (1862), and Machinery and Mill Work (1869), is likely to have been a primary component. These 'Manual(s) of..' were each major works. They were typically of 600 pages or more, and in their day were expensive. The '*Civil Engineering*' was the most expensive and remained at the price of 16/- (16 shillings) into the twentieth century, despite the severe economic depression and deflation in the 1890's. Topics such as Rankine's well known studies of theoretical soil mechanics, the active and passive states, deformation patterns and the like, are dealt with in both his '*Applied Mechanics*' and in '*Civil Engineering*' for good measure. Just what role books such as these played in the education of the young engineers, and may be also of mature engineers, has not been studied in any systematic way. Having association copies is a start in the study of their influence on the profession. Mainwaring is not included in Furkert,[**3**], and it seems little is known about him. However he is shown seated in the front row in a 1901 group photograph of senior NZ railways personnel, in the Railways Gazette, Vol 1 1926. Mainwaring may have become a qualified engineer. What we do know is that he was appointed to the newly created senior post of Railways Land Officer in 1880, a post he still occupied in 1901. By 1926 this copy of Rankine's CE was in the possession of A.R. Callander (d.1950), a licensed surveyor and civil engineer, then of Levin, and later of Christchurch. His son, R (Bob) A. Callander (1925-2007), who possessed the Rankine copy for many years, retired from the Auckland Engineering School staff, after a varied and very productive career, about 1988.

Another association copy, J.J.C.Bradfield's copy of a later edition of Rankine's '*A Manual of Civil Engineering*', was probably bought new by him and is now in the rare books collection of the Fisher Library at Sydney University, [**5**]. The edition and ownership marks are consistent with the book being acquired by Bradfield when a student in the then relatively new Engineering faculty in the University of Sydney. Bradfield (1867-1943) had migrated from Queensland to study at Sydney University since engineering was not a course of study available in his home State at that time.

Provenance - ownership history - should be a highly prized adjunct to the materials themselves. It is especially so in the world of literature. The suggestion is that we as engineers need to give much more consideration to preservation of such information if we are to be taken seriously by other sections of society when it comes to understanding and valuing heritage matters. A.R.Callander, from earlier in this Section, purchased new, at intervals, the three volumes of F.G.Royal-Dawson's pioneering books on roading: alignment , curve design and multi lane highways. These accounts were published by R-D after he had retired from a busy professional life in the Indian Railways and as a Professor in the newly established University in Cairo. These were the formative years of the technology. The volumes were published in 1932, 1936 and 1938, respectively. The texts introduced many new features to English language readers, such as lemniscate shaped road curves to enhance road safety as vehicle speeds increased. ARC was evidently wishing to be well informed about cutting-edge road engineering. The final volume considered multi-lane motorways and the use of flyovers to separate crossing traffic streams. This was almost the equivalent perhaps of 'spaceage' infrastructure at that time. Some Italian Autostrada's and German Autobahn's were built in the 1930's. ARC's three R-D volumes survive. They have clear ownership marks and dates to clinch his having purchased them new. The subject matter, especially of Volume 3, describes some roading types that did not exist in New Zealand at the time. We should remind ourselves that for some years after WW2 there was no fully sealed road from Wellington to Auckland via Taupo: there remained several long stretches of shingle covered, unsealed carriageway. Motorways of the type considered by Royal-Dawson (b.1867-) were still about a generation away into the future for most countries. Bought new the purchase price of the first volume was 12/6d. This compares with the daily pay rate of 7/6d for a married NZ Trooper on active service during WW2. The conclusion drawn is that such books were expensive.

There are also other types of media in relation to archives, besides books and 'hard copy' of various sorts. Sound recordings of conversations with engineers, most often made when the subject was in retirement, offer another perspective on the engineer and his/her/self, [**6**]. Photographs of works and portraits of individual engineers, as traditional likenesses, or photographs, are also an attractive and informative media. Not all the relevant portraits maybe available for display in public collections, except for special events, but knowledge of a portrait's existence and whereabouts is itself important information. The IPENZ website is a growing resource and will no doubt become more important in the future.

6. SOME SPECIAL CASES.

Special status might attach to particular individuals. Three related examples of engineers in this category are New Zealanders John Britten (1950-1995), Bruce McLaren (1937-1970), and A. G. (George) M. Michell (1870-1959), to take an Australian example. Their individual successes are quite well documented, mostly on the internet, but there is always more that can usefully be added before the personal memories become too vague. Britten is probably the least well known of the three. On 11th February 1995, a few months before his death, he was invested with Honorary Fellowship of IPENZ at the IPENZ Annual Conference, held in Palmerston North that year. McLaren, the GP racing car driver and very successful constructor of F1 and Cam-Am cars, has had little, possibly no, recognition from IPENZ. Michell on the other hand is regularly commemorated when the Michell Medal, one of the premier I. E. Aust awards, is made despite AGMM's resolve in his lifetime to decline Institution membership.

It is Britten's near singlehanded pursuit of a dream-like goal for motorcycle race competition success, as a designer and constructor, that we remember him for. It would be of interest and relevance to know whether Britten was himself influenced by McLaren's earlier success as a competition car constructor!

McLaren started his engineering studies at Auckland University but did not complete them. His motor racing successes began when he was still in his teens. McLaren was mentored by Jack Brabham into the Cooper Cars works team and, despite a degree of physical disability, he very quickly progressed to the world stage. He became the youngest ever winner of a F1 race to that time. This was in the first post WW2 US Grand Prix F1 race at Sebring in 1959. He was aged 22. This race also sealed Brabham's first World Driver's title. Within a few years, and after following Brabham into founding a team of his own, Team McLaren had success as constructors of F1 and, more spectacularly, Can-Am race cars. Today the F1 team that bears his name is the second oldest, after Ferrari.

Michell was a genuine polymath. Highly trained academically for the time, from the outset of his working career he practised as a consulting civil, hydraulic and mechanical engineer. It was not long before he had spectacular success as an inventor of major technology in the lubrication field. This technology was commercialised very successfully before WW1, primarily through a joint venture in the UK. His technology played a significant role in WW1 naval technical advances. Then, in middle life, he developed his 'crankless' reciprocating internal combustion engine. For about a decade he devoted his considerable skills and resources, full time, to the commercialisation of this engine type. Despite the merits of his invention, success eluded him.

There is active pursuit of archive and preservation by the Bruce McLaren Trust, which has family participation. This relieves IPENZ of some of the need to take an active part. This writer is not well informed about the Britten archive situation. So far as Michell is concerned, it seems agreed that much vital archive has been destroyed. This is a major loss. A good (auto)biographical record is available since Michell wrote his own obituary for the Royal Society of London, of which both he and his elder brother were Fellows. This gives some perspective to the distinguished contributions that they made to academic and practical studies related to engineering. Much that the brothers pioneered has had important technological value. Almost all the hardware, such as experimental engines and the several road vehicles which were fitted with crankless engines, it appears has not survived [**7**]. Given the dominance of the road vehicle in modern society, and knowing something of the long and sustained effort and expense that Michell expended on his brainchild, it is both strange and regrettable that this should be the outcome. Michell's experiences provide a good illustration of the vicissitudes in the life of a very talented and successful engineer who struck out on his own to convince the motor industry, especially in the USA, to take him seriously. But success, as measured by acceptance, eluded him. This had a profound effect upon him in his declining years. The disappearances of the crankless engined Austin and Buick cars,[**7**], and other examples of the technology he created, remain as mysteries,[**8**]!

These three engineers have generated special interest by their achievements but they are relatively unknown in the public domain. They are by no means alone. A comprehensive survey, with on-going updating, of member's achievements is a legitimate function for a professional body. Over a period this could lead to publication of biographical and/or historical material highlighting engineering achievements - later versions of Furkert and Newnham you might say. It is the case that the Furkert and Newnham volumes were produced by Institution members when in their retirement. The evidence seems to be that neither work was regarded as especially notable at the time. Today they stand as notable, and valuable. From other observations made in this paper and elsewhere, the profession should probably accord them an even higher category of value. Let us explore in what role active current members might contribute, and from more than just the ranks of the retired, to the conservation of biographical archive in the future.

7. THE PRIORITIES FOR THE PROFESSION - 1.

The priorities for the Profession in the quest to secure the permanence of archive collections, and their availability for use by relevant persons, is a many sided enterprise. Most commonly, libraries or museums are thought of as the primary repositories for archives. This will probably be the pattern in the future also. The internet is a quasi-library of evolving form. But how permanent is material on the websites and how reliable is it? There are no ready answers available. Important and attractive as most aspects of the Internet are, there remains a need to seek, assess and preserve conventional archive materials of most types. In the early years of organised professional institution development in NZ the growth of an in-house library was actively pursued and reported on in their technical journal. In the 1960's the policies of the day brought about the dispersal of that collection. The writer is not well informed about the Australian experience and practice. There is a library maintained at National HQ in Canberra. The I.E.Aust when at Science House in Sydney had a library. It is presumed that this found its way to Canberra. The MOTAT collection in Auckland is a very valuable resource, as are other similar collections elsewhere in NZ and Australia. The case for direct support from IPENZ to such entities is strong. Some IPENZ members have, as individuals, contributed to these collections over the years. A recent growth point is the rising interest in IT related archive, particularly the hardware, early digital computers and software related materials.

A new start has been made to collect a range of archive materials again by IPENZ in Wellington. This is good news and hopefully will result in a useful collection of archive materials in due course. Relevant materials may remain in family possession for long periods. This outcome could be by choice or may arise from understandable indecision and/or through lack of suitable advice about possible value to the profession. Personal archives may be offered to repositories such as the National Archives. Not all such offers could expect to be accepted. Yet other materials may be accepted by regional libraries. Some desirable materials may be disbursed by public auction or in the trade. From time to time important collections are dispersed. The currently proceeding Macclesfield library book sale of scientific and related subjects in the UK is an example of a little known but very significant collection now being processed through the auction sale route. There are limits on the scope to purchase such a valuable collection for the nation but hopefully this has been considered.

The profession could be expected to have a policy on collection of archive materials. A part of this could include on-going publicity on the institution's website, and in official publications, describing the policy and outlining priorities such as seeking to identify collections of books or other related materials that could be considered desirable for the professional body to acquire. Some of the libraries of the nation's educational institutions, for example those of the engineering schools, do have modest collections of engineering archive. Much of this material has come as bequests and unsolicited gifts. The Architecture Library in Auckland also collects archive, with some over-lapping into engineering. Generally the staffing of these libraries does not extend to appointment of specialist librarians to take care of these collections. If this continues to be the situation, in time this means a deterioration of the holdings, as experience has shown. It should also be appreciated that whole sections of some of these library's holdings of technical works have been disposed of in recent decades. In some measure this has been by sale but destruction has been the fate of much of this class of material. Lack of shelf space and infrequent use of the material have been the primary factors in taking such decisions.

What then is the prospect for building up archive collections and ensuring their security? This is a very difficult question to resolve satisfactorily. Then there are questions about geographical hazard: for example earthquake in New Zealand, and may be bush fires in Australia. A preference this writer has is to consider a dispersed system of libraries equipped to house archive as well as secure housing in the profession's own (regional) offices/meeting places, and with each centre seeking local materials. Maintaining and adding to the existing collections of archive by IPENZ and I.E.Aust. requires resources both of funds and personnel to care for the materials. In the case of IPENZ this is a reversal of the policy adopted about 50 years ago, when the then in-house library and some unknown amount of archive was disposed of. The current membership will no doubt have views on any new policy. In addition there is a sound case for encouraging researching and writing essays on an undefined number of engineers whose very successful working careers are not well documented. Many worthy subjects are easy to identify.

For example, a prominent early engineer who is not in DNZB but is included in Furkert,[**3**], and whose career remains far from fully explored, is Harry Pasley Higginson (1838-1900). His professional experience was gained in several countries before he came to NZ. Furkert records that Higginson arrived in NZ in 1872 to take up the Superintending Engineer role for Railways and other public works in the South Island, based in Christchurch He remained in this post for about five years and is credited as being the designer of the combined rail and road bridge at the gorge site on the Waimakariri,[**3**,**11**], during this time. This bridge is still in use, though the rail access has been removed. It is one of the finest bridges of its type anywhere. The completion date is given as 1877 [**11**]. We can ask many questions for which at present, it appears, there are no answers available. How and where was it designed, do any working drawings exist, where was it fabricated and what methods were used to erect it ? These are just some of the questions it would be worthwhile to find answers to. It is tempting to expect that sufficient iron founding and fabrication capability was available at the Anderson engineering business in Christchurch at this period. Did they play any part?

The site is relatively remote and would have been difficult to access in the 1870's. The piers are founded in the boulder strewn river bed. The deck is more than 30 m above bed level. Building such a structure would provide many challenges even for us moderns. The piers are worthy of note: they consist of iron segments forming a hollow rectangular shape with semicircular ends, [**11**]. These were probably sunk into the river bed by controlled excavation of the insitu materials inside the assembled segments. As sinking progressed more segments would have been added, and this process continued until an acceptable foundation was achieved. Then the above ground 30+m high hollow pier shaft would be erected in stages as the pier was progressively filled with concrete. A less ambitious but innovative use of wrought iron to fabricate hollow bridge piers to be filled with concrete, was employed on the Whataroa River bridge in South Westland, [**11**]. (A similar method, but applied to building structures, was used by R.J.P.(Pat) Garden at the Burnside Freezing Works near Dunedin post WW2. In the 1990's a NZ Patent, No: 227555, was granted to Uniservices, the commercial arm of Auckland University, for a generalisation of the technology.)

There is no definite link established between the design of the Gorge bridge and Mainwaring's copy of Rankine's 'Civil Engineering' described earlier in Section 5. It is tempting to think however there could be a link since 1873 was when the Rankine copy was purchased new in Christchurch and was also when Higginson, just recently arrived in Christchurch to direct operations in the railway department, would have had the Waimakariri Gorge bridge in his office to be designed. This speculation is being made because the method of pier construction employed on the Gorge bridge is described in some detail by Rankine in his Article 406. There is further elaboration in an Addendum in this particular edition of 'Civil Engineering'. Art.406 also includes a discussion of using compressed air to balance water pressure when working below the water table. There are few details given but that such techniques are described at all seems amazing, considering the work environment on sites at the time. The book was both a text for the young engineer and a source of ideas for the civil engineer when in employment. From what dates are known about Mainwaring, this particular copy could have served him in both capacities during his career.

This brings us to ask, who were the contractors for the bridge construction, or was the bridge constructed by the Railways Department that Higginson had shortly before arrived in NZ to take charge of ? Some of these questions may have known answers, but they are not known to the writer. Answers to even a few of these questions would add considerably to our knowledge of how these pioneer engineers achieved what they did. This is presumably one of the motivations for collecting archive: to assist in reconstructing segments of past activity. Higginson remained in NZ. He went on to a number of other construction projects. His final post was with Wellington Gas Co.: he retired in 1898. He is one of many engineers, his contemporaries especially, some of whom are included in Furkert's ENZE, whose skills and achievements we still continue to benefit from, but about whose careers we have only limited knowledge. The Gorge bridge is a sufficiently novel and interesting structure of the period to warrant more detailed study.

Earlier we noted that the architect but not the engineer is identified on the official plaque on the Auckland War Memorial Museum. Many other similar examples of the engineer not being identified on foundation stones and commemorative plaques can be found. A useful task would be to compile a list of such omissions and then consider approaching owners of relevant infrastructure to suggest the engineer's name be added at the site. This sort of data gathering, being locally based, has the advantage of spreading the involvement around the membership and might unearth some unexpected facets of the particular works.

8. PRIORITIES FOR THE PROFESSION - 2.

Most of the discussion thus far deals with assembling and conserving various forms of physical archives and related materials. Here we consider a quite different aspect of our engineering heritage. What is discussed in the earlier parts of the paper relates primarily to the past. Here we consider the future: in particular the educational environment for the engineers of the future. We seek to outline the case for the young engineers, and other professionals with whom they are likely to work alongside in their careers, to be encouraged to study aspects of their respective professional heritages while still studying in the formal learning environment.

Courses in the history of engineering and, less commonly, of technology more generally, have been offered for many years as electives in the engineering schools in Canterbury and Auckland. The respective course structures have meant that for many of the years that these courses have been taught only students in Civil-based departments have been able to enrol. The same may or may not be true of other engineering schools. Staffing changes at Auckland and Canterbury recently could mean that these courses will no longer be offered. Adding courses to an already crowded degree structure is difficult: offering such courses as Electives may be the only avenue available. This would be a satisfactory outcome, so long as the degree regulations allow students in all specialities to participate. If such courses are successful then there would be scope to build on these beginnings and enable the subject to develop and evolve.

In many universities world–wide, and in relatively recent times, flourishing History of Science departments have developed. To be more specific, these are usually departments of 'The History *and Philosophy* of Science'. If we are serious about the subject of engineering heritage, then there is a strong case that we should be promoting serious studies in '*The History and Philosophy of Engineering, (or of Technology)'*. Particularly in the present global environment, the need for, and scope to assemble, a very worthwhile course for such study has never been greater. Study at an appropriate level within a faculty, with the possibility of separate departmental status sometime in the future, presents exciting prospects. At least one such study centre nationally would be a sound investment for the future.

Without a doubt there is ample scope to evolve courses that can both inform and intellectually challenge the best of the students in the future. If this outcome can be achieved then there is an enhanced prospect that there will be better dialogue and debate in the community, and between the professions, when national priorities with heritage implications are being set. The result should be greater scope for current and future community expectations to be met. The present economic crisis, and the political responses this is producing, is only likely to bring about improved outcomes if a 'long view' can be developed rather than continuing the short term thinking and decision taking that has dominated recent decades. This is another way of saying that we need to be better informed about the past, and in a more systematic manner, than we have been for decades. Engineering is mostly seen as a means to an end. The suggestion is that the engineering profession itself needs to be better informed and have a more rounded view of the engineer's role as to how the past contributes to the future. This is where the '*philosophy*' should be coupled to the '*history*', to produce an augmented study for future engineering heritage issues, and an interface with related disciplines.

Another aspect of 'heritage' issues in a general sense being legitimate course content for study in an otherwise vocational degree course such as engineering is that such 'history and philosophy' courses have the scope to perform a unifying role in what is currently a fragmented intellectual environment of autonomous and separate courses of study. Related to this circumstance is the possibility of dialogue, and hopefully fruitful collaboration, both for teaching and research, with Departments in the Arts and/or Science faculties. In some respects the advances in understanding engineering heritage, in the sense of academic study, has already been annexed by some 'History and Philosophy of Science' Departments around the world. An example is the recent extensive wealth of research that now surrounds figures such as Thomson, Maxwell and Rankine, the nineteenth century 'Natural Philosophers' and early engineering academic whom we have encountered in earlier sections of this paper and whose legacy, with others, provides the foundations on which much of our modern day engineering technology is based, [**12**].

There is much of value and interest in the achievements of the profession as a whole, over centuries. Mainstream history teaching and writing often refers to the products of engineering but often the professionals responsible for the creation of the works are not identified. The politicians *are* likely to be identified and discussed, but the professionals such as engineers are much less likely to feature! Some appreciation of heritage issues can be studied in the educational and vocational training phase, as well as during the working lives of the membership. The IPENZ Foundation - a recent initiative by IPENZ to widen the scope of outreach to the community at large has some stated aims that are close to some of the initiatives briefly described here. Recently received correspondence from the Foundation notes ' ..you are probably concerned about the low profile engineering still has in our society.'. This is a point discussed earlier here. But there is no single clear path to follow to overcome what many perceive as an ongoing concern for the profession. After adequate discussion, if a consensus can be reached, the sort of academic developments described in this section have the potential to provide a new initiative for the cultural underpinnings of the profession to be strengthened. There will be costs to be considered if a proposal to add courses for degree study is to be implemented. A suitable case must be made, with inputs from the profession, to the relevant academic agencies. But before any progress can be made the profession itself must consider all the relevant proposals and be convinced of the merits for the educational process as well as the medium and long-term benefits for society generally, the individual professional, the profession and engineering heritage studies in the widest sense.

9. A NATIONAL TECHNICAL LIBRARY!

This topic has been touched on earlier and has been left till last to discuss, since it is the least likely to be implemented any time soon. Suggestions for a big budget item such as a National Engineering and Technical Library, one of whose major functions would have to be archive collecting, have been made at various times in the past [**9,10**]. The original suggestion for such a national collection was probably that made by Evan Parry, an electrical engineer, on the eve of his departure from New Zealand in 1919,[**13**]. Parry had taken a leading part in introducing electrical power in New Zealand and was held in high regard. In the ninety years since, his original suggestion has hardly been discussed or taken any further. It could be argued that some of the spirit of what he was proposing was built-up in-house in the Public Works Department and Ministry of Works during their respective periods of dominance on the national scene and in the quasi public domain. With those collections now dispersed or alienated, in a sense the case for a National Technical Library goes back on the agenda.

Modern society, in the Western sense at least, depends vitally on employing technical services throughout the community. It is surprising then that there are not more robust library facilities specializing in the whole range of technologies spread throughout the nation. Teaching and research institutions would make the greatest calls on a facility such as a national technological library. As at present structured, the libraries at the engineering schools for example, cater for their students and staff as best they can. Archive functions do not feature highly among these services. Judging by some other National library structures, one feature that should be better represented in NZ than at present is archive collections relating to engineering and technologies generally. Enhancement of archive collecting in the technologies would put unexpected pressure on the capacity to house newly acquired materials as well as on requirements for specialist staff. Realistically the need would be a separate library and possibly sited away from Wellington, for safety and user reasons. Potential sites have been suggested [**9**].

It would be in keeping with some overseas practice if a National Technical Library was also a Deposit Library for relevant materials covered by the local Copyright Act. How effective such a facility might be depends critically on the provisions of that Act. As at present structured the NZ Act would be of little benefit to a National Technical Library via deposit requirements, because of the narrow definition used for the meaning of 'published'. In the modern state 'published' should be synonymous with 'distributed', as is already the case with many of the older and more powerful nations. The present economic climate is a further reason why establishing a National Technical Library seems unlikely. But this is not to say that potential interested parties should not think through the priorities and benefits of such a facility. Nor should in-house collection development of archive materials be put on hold or not considered important. A prelude to future success in achieving a national collection with a primary focus on technology, including engineering, will in all probability only be after there has been greater participation in heritage conferences and the like into the future. Opportunities to acquire private collections and to benefit from bequests will be restricted until the whole concept has been fully debated, prioritised by the membership and the results communicated to potential donors and other sources of materials.

10. CONCLUSIONS.

Several public domain libraries in both NZ and Australia do have active policies to accumulate relevant engineering archive. But it needs to be acknowledged that the status quo is not attracting an adequate proportion of the potential archive of value into these collections. Our professional bodies need to revisit their policies on collection of such material and then discuss with other associated professions, libraries and museums whether there are further collective strategies that could assist with the gathering and making their collections available.

Proposing that the profession invest more resources and effort in seeking archive materials in a more active fashion may not meet with the support of a majority of colleagues, especially in these uncertain times. Fortunately there is much that the individual can achieve, even if collective or Institutional support and encouragement might be lacking. The hardware that professional engineering produces to enable a modern society to function is there for all to view and evaluate. These facilities have owners whose interests include the maintenance and continued functioning of this hardware. What is often poorly documented at the time such hardware was created is the personal details of the engineers and other professionals whose expertise gave rise to the creation of the hardware. If not well documented at the start the task of reconstruction later becomes difficult or may be even impossible. The contributions of several individual engineers are raised in the above paragraphs. Serious and worthwhile progress towards accumulating biographical data in particular is improving but much more could usefully be done. Collective effort will speed the process but individual effort will always have an appeal and adherents [**11**]. One measure of the effect of the 1980's upheavals relating to many records and archive materials of the Ministry of Works would be to know the present whereabouts of the sources used by the author,[**14**], when she was researching the history of the Ministry of Works a decade earlier.

The internet has an important role to play and will provide useful facilities for us all. The question of reliability and accuracy of Internet material will remain. However, this is not a competitive environment in the sense of winners and losers. Rather, the growth of the internet will add value to the original source materials themselves, from which the internet draws its copy and content, rather than in any sense make these source materials redundant. Hence there will be no reason to cease seeking to identify and ensure the preservation of original materials.

The time has probably come to review whether in Engineering Schools there should be content available in the B.E. Degree, and in the post graduate programmes, to study the '*History and Philosophy of Technology*'. This could be a sensitive issue with History and Philosophy in the Arts Faculty. There will be costs to be met. The benefits may take time to be felt. In the future this field of related study to mainstream engineering has the potential to reposition professional engineering in the social fabric, and in a beneficial manner for all parties. How these prospects can be assessed is not easy. The way forward is probably to move in this general direction as and when personnel and resources can be identified as being available.

A recent book, [**15**], though not dealing with engineering heritage, is an example illustrating what a benefaction can achieve for future generations in the field of cultural heritage. Engineering heritage collections could possibly benefit the community in the future if long term interest in the merits of heritage conservation can be seen to include technical as well as literary and other general cultural aspects.

This paper is dedicated to the memory of colleague and friend, Dr. Bruce Gamble (1942-2004). He, and his co-author Ian Stewart, [**16**], contributed an important paper to the second conference in this series. Both devoted much time to MOTAT, the transport and technology museum in Auckland. Several of the points made by them in 2000 are earlier expressions of points discussed again in the present paper. Their paper was awarded the inaugural Pollard Prize for the best paper at the Engineering Heritage 2000 conference. John Pollard (1923-1999) was intimately associated with the first conference in the present series, held in Christchurch in 1994. He was one of the founding fathers of engineering heritage studies in New Zealand.

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APPENDIX 1.
THE PAST INTO THE FUTURE.

One theme in this paper has been the alienation and/or loss of important engineering archives during the process of changing from government to private ownership of the Ministry of Works and other former government agencies. Only some of the losses have been identified. The core archive of major infrastructure completed during previous eras, such as as-built drawings and all the associated materials, has in many cases passed out of public ownership and an unknown portion of it has been destroyed. The same is true of Lands and Survey, the Railways and Electricity infrastructure. Looking back at the last twenty five years there has been a huge diminution of public domain engineering archive. Future generations will have to wrestle with the consequences.

Public pride and interest in these key infrastructure projects has been harmed in the process. There is ample evidence to show us that NZ Railways has a proud history. For example this arm of government of the day pioneered the design and deployment of the 4-6-2, Pacific Class, of steam locomotives in c.1901. The Pacific Class went on to become **the** most popular class of steam locomotive of all time. The passenger rail network in NZ was a key piece of nation building infrastructure. Today only a remnant of this service survives. With the recent re-purchase by the State of the rail network, and the scope that rail presents as the one transport mode able to meet the most stringent global warming targets, let us plan for a future where rail re-emerges as a preferred, efficient and environmentally sustainable means of both commuter and long haul passenger as well as freight transport. It seems to this writer that such a resolve is a natural outcome of the study of our Engineering Heritage. Studying the past to help us make wise decisions in the future is a core reason for such gatherings as the one we are attending. The present global financial instability is in these terms a wake-up call, to smaller nations especially, to examine the past carefully and to map out a more stable future, where local ideas and expertise are given a better chance to provide for future national needs. Rail in NZ has had an exciting and illustrious past. Current conditions present the mix of novel circumstances that could enable a revival of this earlier success.

Ref [**16**] details the considerable effort applied, as well as the difficulties experienced, in building the tramway system in Auckland, now over a hundred years ago. The trams served the then 'pioneer' and rapidly growing city of Auckland very well for fifty years. Then, quite quickly, about fifty years ago, and without much discussion or analysis of the consequences, all of this infrastructure was swept away. The uncomfortable feeling is that for the past several decades our cities have been deprived of the planning foresight shown by our grandparents' generation. Let us hope that this situation can be retrieved! Provision of a comprehensive generic urban public transport system, capable of providing a service superior to the private motorcar, is one of the unsolved civic problems in our cities and communities. Engineers have much to contribute to the discussion and decision taking. All the options need careful study. Most particularly, sub-surface rail should be in the mix. Several such systems in other cities around the world have celebrated their centennials. These systems have not been scrapped. Rather they have been added to. Appropriate heritage studies could serve to better inform the public, and arouse their interest, as an alternative to the political spin and lack of coherent planning that our communities often currently experience.

We are fortunate that there are several excellent books about NZ Railway's era of importance. The 2007 published '*Trainland - how railways made NZ' by Neill Atkinson* is a valuable recent survey. The reference section is especially useful for the non-specialist reader. David Leitch's 1972 '*Railways of New Zealand'* retains a special place in the literature, as does R.S. Fletcher's '*Single Track'* of 1978. Let us hope, and study the prospects, for a revival of the urban rail systems, more especially for a modern Underground(U/G), especially in Auckland. Making such an ambitious statement may harm personal credibility but we should have absorbed from the study of the past that ambitious, but well thought through, schemes is what is currently needed, given the timidity of much of the decision taking for public domain projects in the recent past. A brief but worthwhile glimpse of the contribution made by one individual in the railways scene in NZ is the essay in DNZB5 by the late Nigel Stace where he writes about P.R. Angus's contributions to locomotive design: the K and J loco era! Fifty years on from now it would be fitting if similar essays could be written about local engineers having designed and built the underground track, passenger access and the rolling stock for a successful underground urban rail system in Auckland, for example.

The decisions facing our communities today relating to all aspects of global warming are important and not easily dealt with. Transport issues are a major component in the total picture. Judged by the content of the current public domain discussion, railways in both New Zealand and Australia are being more talked about and hopefully there is planning being undertaken by various agencies to rebalance the rail/road divide for passenger/freight transport nationally. But the conclusion thus far seems to be that the road vehicle lobby has by far the more active presence in the corridors of power. For example, discussion is well advanced in New Zealand to allow a substantial increase in road freight loads. The present 44 tonnes limit per unit of road haulage is being talked up to 53 tonnes. If such an increase passes into law the road haulage industry will be the beneficiary. This will be another victory for a sectional interest. The downstream costs through damage to roading infrastructure will be substantial and difficult to quantify in advance. If the limit is raised, as a co-lateral adjustment, the road user charges should at least be subjected to the same fourth power law as is expected to apply to the damage caused on the roads by the increased weight. No doubt there would be stiff opposition from the road hauliers to such a proposal. Any such sector benefits should be coupled from the outset with the charges the sector must expect to pay.

Enhancement of rail freight services, both in the public and private sector, needs to be seriously considered as a means to better balance the resources between rail and road. There are many insights to be had from a study of the evolution of rail and road developments over the past one hundred and fifty years. Also this is one activity that can be mounted with a relatively modest budget and can involve the whole community, from the young through to the old. The young could best be thought of as students working on a variety of related projects in their degree studies. Part of the studies should delve into passenger rail traffic, both urban and long distance, and to propose means that would need to be met to rebuild the usage back to what it was in the 'prosperous' period of the earlier history of rail travel.

In principle a railway system could be developed to use a wholly sustainable energy supply. Neither road vehicles nor aircraft can achieve this independence from sustainable (fuel)energy. Track-side banks of photo-voltaic panels coupled to distributed storage of energy in mini pump storage installations to utilize excess daytime power generation could be one scenario. There are many others. The incentive to consider novel methods is greater today than for decades. The opportunity should not be lost. The young professionals are the agency for such activity to thrive. There have been few positives emerging from the 2008 global financial crisis. Hopefully a shift to consider novel approaches in all manner of activities is one of the few benefits that might arise from the wreckage strewn aftermath of the global financial melt-down. This also fits well with the need for society to offer fresh incentives to the young in our communities to make constructive and potentially important contributions to the general good. 'History' and 'philosophy' have a role for the profession to consider in such times.

Auckland and Sydney, both key cities, are deep into dependence on the motor vehicle. Underground passenger rail systems are being constructed in many countries, in both the developed and especially the developing world. But none more so than in China. The Chinese are building new U/G track at such a rate that in a typical year, a similar length of track would provide Sydney with a new, fully comprehensive, region wide, urban public passenger transport system to satisfy all current and medium to long term future needs. Small nations are no doubt less capable of equipping their cities with such vital infrastructure! At least this is the response most often met with. As engineers we should be seeking the means to achieve such goals without generating a massive public debt burden. History shows us that analogous schemes were achieved in the first period of the railway era, and in cities far smaller than a present day Auckland or Sydney. Glasgow for example, [**17**], built an inner city U/G which has celebrated it's first hundred years. Parts of the London U/G are even older. Sydney has had it's 'Bradfield' era but even he had to wait a decade and a half before the main features of his proposals were implemented. What would he be thinking, planning and doing were he in his prime today?

Above all, we need the commitment from all, the public, the professionals and the politicians, to act on a twenty year time scale of infrastructure spend,[**18**]. Hopefully the financial excesses, risk taking at no personal cost to the takers and encouragement to personal greed, ushered in by the de-regulation era in the late 70's, have come to an end. Then long term good for the whole community, especially in transport terms, consistent with the achieving of global warming goals, could be upon us. Engineers we know have much to offer in such an environment.

APPENDIX 2.
PERSONAL ARCHIVE.

A worthwhile category of archive materials that could be selectively sought is personal correspondence and other 'association' materials. This is also one of the most vulnerable of categories of archive. Generally it is relatively undemanding of storage space. As an example, one small, known collection contains 'correspondence' received from the following on technical related subjects: E.(Eric) Ashby, A. G. Bagnall, J.F. Baker, J. C. Beaglehole, G. S. Beca, A. G.(Gordon). Bogle, K.N.E.(Bill)] Bradfield, family of Arnold Downer, C.W.(Cyril) Firth, E.(Eustace) N. Fox, C. (Charles) A. Fleming, R. J. P. (Pat) Garden, C.E. Inglis, N. (Neil) A. Mowbray, family of W. L. Newnham, Osborne Reynolds, I.(Ian) B.Reynolds, J.W. Roderick, family of F. S.(Stan) Shaw, L.(Len) Southward, R.V. Southwell, A. (Alan) L. Titchener, L.(Larry) B. Watts, H.A. Webb, L.(Les) C. Woods and others.

3rd Australasian Engineering Heritage Conference 2009

Telling Engineering Heritage Stories

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Conference case study by Tom Williamson, Filmmaker, Wellington, New Zealand.
Presented to the 3rd Australasian Engineering Heritage Conference, Dunedin, 2009.

SUMMARY: *Engineering heritage is one of the most difficult areas of heritage management. On the positive side, two engineering heritage places are highly popular with the NZ public. For any heritage place, the essential element of long-term success is to effectively communicate its value in a manner that will capture the interest of the next generation. Modern audiovisual has great potential to both preserve engineering heritage and also communicate its value, and it must be used more widely.*

This paper sets the strategic context for Tom Williamson's conference presentation on the power of audiovisuals as a medium to both preserve and to tell engineering heritage stories.

1. MANAGING HERITAGE

Heritage involves people. Success in heritage involves being successful with people. Heritage is not predominantly a technical 'preserving' activity; it is equally a cultural 'valuing' activity. Heritage requires us to use communications to succeed in gaining people's interest and support. Crucial to this is getting people to see the value of heritage. In fact, when we focus on winning people's interest and support for the values, we find the 'technical' then tends to take care of itself.

The link between heritage and people's values is stressed by many heritage leaders. For example, in 2004 when ICOMOS celebrated its 40th year, Cevat Erder of Turkey was invited to contribute reflections and aspirations. Cevat is an eminent international ICOMOS leader, a foundation member who served nine years on the executive. Of the future he stated: "One should always keep in mind that the (cultural) attitudes of people towards their own heritage is fundamental. Only in this way can one correctly diagnose and cure the ailments affecting cultural heritage. For those that think that conservation is basically and merely a technical problem, I am thoroughly opposed to this belief, and take side with those who think that conservation is above all a cultural issue."

Where would we look to find the most effective way to get people to see value? We would look to the techniques of marketing. Around the world, it is the effective marketing of values that produces the strongest results. Professor Sam Ham of Idaho State University is considered a world leader in interpretation practice. He strongly advocates applying the marketing approach to creating effective interpretation of heritage sites, and it can be applied to heritage site management overall.

In order to effectively communicate heritage values of a site, the leading messages must be simple and clear. This often means that from several heritage values identified, we must select a single key value to lead communications about the site. This lead value is the one that is most likely to win the interest and support of people. Ideally we work on expressing this value in a single engaging sentence. For example, two marketing concepts useful to promoting a heritage site are the 'compelling reason to visit' and 'point of difference'.

A starting point in increasing success is agreement on exactly what heritage is. A simple clear definition is 'heritage is things of value to pass on to the next generation' and is promoted by Francois Le Blanc of the Getty Conservation Institute. Its simplicity and clarity give this definition great power. Even children can understand it, a vital quality, since we particularly must win children's interest. The table below analyses the elements of this definition:

Heritage element	Analysis
Things	Tangibles: artefacts, places, structures & buildings. Intangible: stories, skills & traditions.
Value	Value can be at a range of levels: personal, local, national, & international value. Values change over time. The work of heritage is to grow value.
Pass on	Essential to effective passing on: 1. The thing must be maintained in good condition 2. Someone must get to value it enough to want to accept it
Next generation	Not future generations, the next generation here now. This is not a task to postpone; it is inherent, vital and on-going

This strong definition exhibits one shortcoming; it can be seen to have a focus on things. Since the critical element of heritage is cultural, then the definition should inherently involve people. Adapting it to define heritage *management* creates a stronger proposition. 'Heritage management is passing on things of value to the next generation'. This clearly requires us to be successful in getting the next generation to value the sites being passed on to them.

Case study 1:
Managing heritage at the 1908 Cape Brett Lighthouse

In 2005 the redundant Cape Brett lighthouse urgently needed painting to save it from serious damage. Step one was to communicate to DOC managers - and Kiwis - why it was worth saving since NZ has 31 other lighthouses. It had no heritage listing.

The value chosen to lead communications was this: 'Cape Brett will be always popular to visit because it is the *only* lighthouse to survive complete in NZ - all the others are gutted shells.' This strong value statement along with considerable internal advocacy persuaded key DOC managers that $450K was money well spent.

Today the painted lighthouse looks durable and it would be easy to think that it is now 'saved'. Not so. In 25 years this paint job will be showing stress, and will need re-doing. This means that DOC doesn't get a 25 year rest from working on Cape Brett.

DOC now faces 25 years of consistent hard work to effectively communicate to Kiwis the value of Cape Brett as a NZ Icon site, a must-do. If we get that right, funding in 2030 will be assured.

Managing the heritage at Cape Brett involves an on-going commitment to an equal partnership: the technical activity of painting together with the cultural activity of communicating value.

Communicating the value of engineering heritage has proved to be one of the hardest challenges in heritage management. How do you win people's interest and support of the value of sites that most people have hardly heard of, let alone seen?

As the motor age developed in the 1950s and 60s, people often included visits to engineering feats in their holiday itinerary, especially new bridges and hydro dams. These attractions have now been replaced by adventure tourism, vineyards and malls. In the same era, school parties visited factories, and some factories even offered public tours, but this too has also largely gone. Even back then, many key major industries were not visited, such as freezing works, dairy factories, and pulp mills. The engineering heritage conundrum then is if people didn't visit an industry in its operational heyday … why would they want to once it is closed?

Engineering heritage in NZ was born more than 80 years ago in 1925 when the national rail system's first locomotive, Josephine, was rescued from the scrap yard and placed on display outside the Otago Early Settlers Museum, Dunedin. It remains there today, indoors.

Over the next 50 years development was slow, but it took off in the 1980s. In retrospect, the vital ingredient was the leadership of Historic Places Trust with John Daniels director and Geoffrey Thornton technical expert. They are the first to point out that many others contributed significantly too. Trust leadership was expressed in the recognition by registration of a range of engineering heritage places, quite visionary, the protection by purchase of 12 engineering heritage properties, the definitive 1982 Thornton book, and the 1983 national seminar with imported keynote speaker Neil Cossons. Another key overseas element was the 1979 Hudson book *World Industrial Archaeology* which provided an academic base.

However within ten years progress reached a plateau because the agency programs soon ran ahead of public support/values. Heart can now be taken from the recent success of two sites that have a significant engineering heritage dimension: developing the Otago Central Rail Trail and Karangahake Gold Mines. A 2007 Automobile Association study identified these two as the heritage sites that Kiwis most aspire to visit.

Case study 2:
Whose values? The Otago Central Rail Trail

The Rail Trail concept was grown from 1987 by a few biker locals, and a DOC ranger, who were aware of the growing success of rail trails overseas. Hardly anybody else could see value in the idea. Organised opposition was led by Federated Farmers who found support in a local MP. Amusingly, support emerged from farmer's wives who could see the potential for bed & breakfast businesses. Somehow, despite the odds, the 150 km trail opened in 1998.

In 2007 the Central Otago mayor, addressing an economic development forum, stated 'the future of Central Otago lies in the Rail Trail.' The former Federated Farmers leader even said on camera 'I opposed the rail trail and I was wrong'. This shows how values change over time. This is the job of heritage to work on value, whatever it takes.

It's not the heritage value that changed attitude, it's the economic value. The Otago Central Rail Trail Trust therefore picks economic value to lead their communications. They research economic value on an annual basis and communicate their findings: the number of bed & breakfast businesses, bed-night numbers, the number of jobs generated, average daily spend, and … the estimated $1M overall economic benefit in 2008.

2. THINGS OF VALUE

Heritage management is the activity of passing on *things of value*. A key step is determining which 'things' are of highest value to keep. We (should) have learned that the value criteria cannot run too far ahead of public support/values, or projects simply do not get funded. On the other hand, heritage is about creating a future for the past, so the value assessment must include a visionary element.

Initially value criteria were based on the *notable*, like the *first* NZ locomotive, Josephine, and the *last* NZ horse-drawn coach at Arthurs Pass, both rescued in the 1920s. In the 1970s emerged the wider notion of preserving *a representative range* of sites. A major NZ work was the 1982 Otago Goldfields Park Strategy by Tony Perrett. While theoretically sound, this approach proved to be too expansive and too ahead of public values to be applied very widely.

The 1980 Historic Places Act set out the 'academic' value criteria to be used in their registration program. These criteria were elaborated in the 1993 Act, but they include 26 different value ideas, which are too many to be applied individually, although the Trust persists in vain. Around the world a variety of value criteria are used, but they all can be, and should be, grouped under three main headings: history, fabric and culture. Values must be expressed simply to successfully engage the public.

In 2007 the Te Ara (on-line encyclopaedia) section on the timber industry tested an alternative more focused approach to NZ's timber industry heritage based on just two value criteria: *outstanding* & *distinctive*, ideas taken from the World Heritage criteria. This approach suggested that the 1930s bush tramway system on Great Barrier Island might be a more outstanding engineering feat than the established Kiwi railway icons Raurimu Spiral, Rimutaka Incline or Denniston Incline. But even this approach is not sufficiently aligned to public demand to be useful.

Case study 3:
Edwin Fox - The Vision of a Future for the Past

In 1940, NZ celebrated 100 years of its founding as a nation when the Treaty of Waitangi was signed with the Maori tribes. From 1840 onwards, tens of thousands of European settlers had arrived by ship. The major heritage achievement of 1940 was the securing and preservation of the Waitangi Treaty site, which is today a key site for national identity and tourism.

Immigrants to NZ severed their family and cultural ties forever and endured six weeks or more of privation to seek hope in a new land. In 1940 an opportunity existed to honour their courage and preserve their story. One immigration sailing ship, the 1853 *Edwin Fox* still survived in sound condition, one of few in the world. The 1940 challenge was to try to see what future generations might value.

Another 50 years would pass before the then much-decayed *Edwin Fox* was rescued for preservation, now in a ruined state. By then genealogy had become one of the most popular hobbies in NZ.

In 2003 the Department of Conservation began its 20 Icon sites program. This was a response to the Tourism NZ 2003 Research into Cultural Tourism Demand which identified the current nature of public demand for heritage. Icon sites are based on criteria that seek to reflect that public demand as revealed by the research. These values define an Icon site:

1. Tells a popular story of Kiwi identity … *which sites*
2. Provides a wow visitor experience that is recommended to others … *how we work*

Criteria (1) is founded on the notion of a high academic heritage value, and favours initially developing those sites whose values are most popular. Criteria (2) is about the potential of the site to effectively communicate those values. The approach matches current public demand, rather than trying to create a public demand through social marketing. Interestingly, half the Icon sites are engineering heritage sites. The growing public success of Icon sites indicates that this is an effective approach to responding to public value.

3. PASSING ON

Heritage management is the activity of *passing on* things of value. Success involves meeting two challenges:

1. The thing to be passed on must be maintained in good condition … and
2. To be successful the pass must be made to an enthusiastic recipient

Tackling these challenges was addressed in two linked papers presented by this Author to the 2005 Sydney engineering heritage conference. Maintaining *good condition* arises from the difficulty of finding a sustainable future use for redundant engineering heritage. The paper 'Saving the Un-savable' offered five strategies to tackle this situation: buy time, invent use, branding & landmarks, finance strategies and build profile.

Creating *enthusiastic recipients* arises from the weak connection between engineering heritage and most people's lives. The second paper, 'Connecting People', provided a toolbox of actions to build public understanding and support, and thus create enthusiastic heritage recipients. The six tools discussed were: marketing, media, partnerships, wow visitor experience, celebrations, and measuring benefits.

This paper follows on from those two. It reviews four management approaches and assesses their success and potential in *passing on* engineering heritage:

- Heritage Places
- Museums
- Archives
- Audiovisual

The first two are mainstream approaches to all heritage that have provided some success for NZ engineering heritage, but have limits. The second two approaches are worthy of more serious consideration from now on. They offer worthwhile alternatives for engineering heritage that is truly unable to be saved.

4. HERITAGE PLACES

A mainstream approach to heritage is the preservation of heritage *places*. This approach offers high authenticity: a heritage place can potentially be preserved as a complete entity and retain the value added by its location. But location can be a liability too: sites in valuable locations face redevelopment pressure and conversely it may be difficult to develop a future for a site in a poor location.

Only the highest *value* places, key places, can be considered for preservation. In fact to try to preserve too much would be socially unhealthy because each generation must be allowed to make its contribution to development. The accepted tool for identifying the most valuable places is the *heritage assessment.*

Once a valuable place is identified, the ICOMOS charter provides guidance on the best *approach* to its preservation. Typically, *options* are considered before an agreed approach is chosen. An essential element of preservation success is *sustainability.* This usually means a viable *new use* must be found and some *adaptation* of the place may be required to suit that new use.

Case study 4:
A New Use for Ormondville Railway Station

Farming is the core of the NZ economy and we once boasted 1000 country railway stations to service those farm communities. During the 1980s the last of these stations faced extinction and immediate action was required to save the best of what remained. This led to the historic Ormondville railway station project, in Hawkes Bay, which aims to combine the heritage of rail along with its total economic and social interface with a rural community.

In 1988 the founders knew of no example in the world where the preservation of a complete country station on a working railway had been achieved. Hurdles included railways culture (opposition to the retention of facilities and to cooperating with outsiders), public safety issues with on-going rail use, and inventing a sustainable new use. Evidence showed that the local museum model was unlikely to succeed.

Success required a combination of approaches, none of which is viable individually, but which can work together to provide a sustainable future. The blend involves a bed and breakfast business in the station building, hosting visitors by charter bus or train, modest rail operations, and a regional heritage preservation group. It has proved possible to retain an entire country rail precinct dating from 1880 including signals, sidings and rolling stock.

The preservation of engineering heritage *places* began in the 1930s when water engineers surreptitiously shielded from demolition the redundant Western Springs pumping station in Auckland.

Since the 1970s NZ has had significant success in preserving a range of key industrial places including these: brick manufacture, bridges, coal gas, coal mining, coastal fortifications, engineering workshops, flax milling, flour milling, gold mining, lighthouses, lime burning, power generation, rail routes, sawmilling, water supply and whaling.

Despite that success, NZ has not managed to preserve key heritage places representing the core economy, the farming industry. Success here might involve preserving a freezing works, a dairy factory and a woollen mill to represent the three principal farm exports. These should be supplemented by other related sites like a sale yards, a milking shed and a shearing shed. Historic Places

Trust made a visionary start in 1980 by securing and preserving Totara Estate near Oamaru, where meat was prepared for NZ's first export shipment.

This raises the conundrum: if people didn't want to visit such places in their operational heyday, why would they want to visit once they are closed and lifeless? Is too great a shift in values required for a historic dairy factory, for example, to ever become a reality? A radical shift in approach may be required. Shantytown museum, for example, met this challenge innovatively in 2007 by animating its historic sawmill. Earlier plans to continue to operate the sawmill small-scale commercially at the museum proved to be not practically feasible.

In terms of genuine operations, Dawson Falls power station managed by DOC stands proudly alone. Its 1894 (circa) General Electric generator still works 24/7 placing it in world class. You can stay there in the up-market mountain lodge that it powers. Three other places offer operations on occasions as special demonstrations: Dunedin gas works, Golden Point stamper battery (Otago) and MOTAT beam engine (Auckland).

In terms of management, most of these engineering heritage places are funded by central government, mostly by DOC. The exceptions are few: council support (gas works), voluntary groups (rail station sites) and private (a flax mill). This situation shows an inherent shortcoming in the historic *places* approach. Places are managed by staff whose positions get funded regardless of results. In contrast, many museums have an economic discipline - they have to be successful each year to survive.

At Denniston Coal Mine, and other recent projects, DOC is seeking to remedy this shortcoming The approach is to entice visitors with popular angles of kiwi identity and to provide a memorable visitor experience. At these sites, visitor numbers and visitor recommendation will be measures of success, not just the number of relics preserved. At Denniston, hosting of visitors to the mine will be a private contract.

The very minor involvement of volunteer groups in engineering heritage also illustrates how hard it is to succeed relative to other heritage. This is why this paper promotes archives and audiovisuals as vital supplementary key tools for engineering heritage.

5. MUSEUMS

Museums usually take things away from their sites and context, a possible down-side. Their strengths are they can provide a secure environment and potential for greater visitor numbers. Most museums featuring engineering heritage date from 1970s: some struggle, some are a huge success; one even closed; none are central government; some are private, with the Caterpillar Museum in Rotorua as a great example.

Museums have to be successful with the public or they may not survive. NZ has some outstanding museums that have a strong engineering heritage theme: Kauri (Northland), MOTAT (Auckland), Tawhiti (Hawera), Shantytown (West Coast) and Ferrymead (Christchurch). Tawhiti is a modest private undertaking that provides an extraordinary visitor experience. Notably, the national museum, Te Papa, has downplayed both engineering and farming heritage.

In the private sector, transport heritage has survived the best: aviation & shipping but particularly road and rail, with a focus on vehicles and locomotives in particular. The rail heritage sector is outstandingly successful; it is voluntary, a well-organised business, and reaches a large audience by offering train rides. I must resist delving too far into the realm of museums as they are an area of great expertise in which I have only limited professional experience.

6. ARCHIVES

Archives have, in theory, a particularly strong role to play in engineering heritage. Most industrial undertakings have proved impossible to retain and preserve as heritage places. Preserving the key relevant plans and specifications would provide a more modest alternative. In reality, there is no NZ archive for such material, and no immediate prospect for one. It would likely take a bequest from a successful retired industrialist, along with institutional partners, to make this initiative happen.

In 2002 Professor Peter Lowe, of Auckland University Engineering Faculty, recognised this need and proposed through IPENZ to develop an archives concept, but the initiative stalled once he moved to Australia. A model is found in the USA where the HAER, Historic American Engineering Record, is federally funded and has assembled a stunning archive of US engineering achievement.

HAER was established in 1969 as a joint venture by the National Park Service, Societies of Professional Engineers and the Library of Congress to document historic sites and structures related to engineering and industry. Subjects range from individual sites or objects, such as a bridge, ship, or steel works; to larger systems, like railroads, canals, electronic generation and transmission networks, parkways and roads. HAER works with a related program, HABS, Historic American Buildings Survey.

The resultant permanent collection of architectural, engineering and landscape documentation at the Library of Congress consists of measured and interpretive drawings, large-format black and white and colour photographs, written historical and descriptive data, and original field notes. The collection captures the American experience through approximately 40,000 recorded historic structures and sites, from American

Indian cliff dwellings at Mesa Verde to space-age technology at Cape Canaveral.

Archival institutions in themselves have little potential to be widely valued by the general public as a place to visit. In fact a growing trend is to visit archives on line, as attested by the success of NZ's Papers Past. It is the job of the researcher and author to transform the stories held in the archives into books that engage a wider public. Thus Hearn and Hargreaves unfold the story of the development of gold dredge technology in Otago. And Bremner, in contrast, captures as the social and economic history of NZ woolscours, 'dark satanic mills' rarely visited by anyone.

Case study 5:
A Future for Tuck's Sawmill Engineering Plan.

Over the course of 100 years New Zealand evolved a distinctive technology of sawmill machinery designed to successfully handle the variable special characteristics of our 'native' timbers. NZ technology was based on adaptation of ideas from North America, England, and Europe, rather than invention. This native timber industry, as it was called at the time, and its specialised sawmills, faded away in the 1980s and little remains. Luckily a complete sawmill is preserved at Shantytown.

In my possession is an original 1.4 x 0.9m detailed plan of Tuck's Sawmill built near Taupo in 1947. This was one of the last native sawmills built in NZ, and incorporated all the best features, a significant step up from the more typical mill at Shantytown. As such Tuck's Sawmill represents the peak of NZ distinctive technology.

Today nothing remains of the mill except the plan. This sets out all the design parameters for the mill, and as such it comprehensively documents the technology. It has a temporary safe home with me, but key issues are who in the future will value this plan and where will it be preserved?

7. AUDIOVISUAL

NZ is very fortunate that from 1941 to 1987 the National Film Unit documented a wide range of NZ life, including our farming and engineering heritage. Much of this footage was custom-shot for the *Weekly Review*, a ten minute, later 20 minute *Pictorial Parade*, both mini-documentaries screened between the cartoons and the main movie. This footage is high-quality and the creative approach taken 50 years ago stands up well with the passing of time. For example, women and children get some strong coverage. Thankfully all this is preserved in the Archives New Zealand, and it offers a rich resource for modern audiovisual presentations.

Audiovisual is a medium that connects with the next generation: consider the success of YouTube. It has also become very accessible: most homes have a DVD player. Niche DVD products are now readily found and purchased on the web. Accessibility will further improve as DVDs become downloadable on line. Techniques like animation permit the reconstruction in an engaging manner of vanished facilities and processes.

Tom Williamson of Upper Hutt is a Kiwi example of a professional film-maker working in engineering heritage. Tom has recently brought to life very successfully a range of industrial themes, and for this reason he is the partner in this paper. His contribution here is a 15 minute selection of material that demonstrates the powerful role that audiovisual can play, and must play in the future, in promoting the value of engineering heritage sites, thus leading to their preservation.

The presentation demonstrates key elements that help bring to life an engineering heritage audiovisual:

- Archival footage
- Contemporary footage
- Animated recreations
- Oral interviews
- Preservation work in progress
- Bringing history to life

Audiovisual might be the only effective way to preserve difficult heritage like freezing works, wool scours and dairy factories. At minimum, a powerful audiovisual is a great first step towards increasing the value seen by the public in that heritage.

Audiovisuals enable us to initially engage people in their homes via short clips hosted on the web. These must be cleverly designed to tantalize. Audiovisual enables us to communicate much more powerfully with visitors on-site or in museums. Research shows that the average person spends very few minutes reading static site panels.

At the North Head Fort in 2009, DOC counted 43,000 visitors watching its new 12-minute audiovisual, with 97% watching the full length. A theatre is not always necessary. A Rail Trail audiovisual could be made for bed & breakfast hosts to show in their lounges to guests. We can reach further into people's homes by selling visitors extended versions of the audiovisuals viewed on site.

It is vital that audiovisual approach and content are skilfully designed to capture the viewer's imagination, so that they come to strongly value the heritage that is being presented. Then we will have succeeded in bringing to life and passing on something of value, which is the essence of heritage.

Case Study 6:
Bringing the forgotten NZ Flax Industry to Life

The story of New Zealand's all-but-forgotten flax industry is brought to life by Tom Williamson in DVD format as a pilot on NZ engineering heritage topics. The flax industry used processing technology specifically developed for NZ.

The heritage core of this DVD is high quality film programs created by the New Zealand National Film Unit in its heyday. These are supplemented by contemporary custom footage including the UK Chatham Naval Dockyards, Dunedin's 100 year old plus rope-works (since closed) and extended interviews with two industry old-timers. Gaps are filled by 200 archival pictures and paintings from museums and libraries in New Zealand and overseas.

8. CONCLUSION

Engineering heritage is proving to be one of the most challenging facets of heritage. This paper sets out an approach that will increase success in the future. The approach is to focus on improving effective communications to win the interest and support of a far wider range of people. Audiovisual is a medium that has powerful potential to communicate heritage values. Once we get the people part right, the preservation part seems to take care of itself.

9. SCOPE

This paper does not define or set boundaries on *engineering* heritage. As a guide, it is the engineering element of any heritage. While traditional farming practices are not included, the farm products processing industries are. However the mechanisation of a farm process introduces an engineering element. This is demonstrated in the mechanisation of ploughing, top-dressing, milking and shearing. Hayes Engineering Works (Otago) represents the early evolution this important link between engineering and lifting the efficiency of farm operations. An element of innovation links the Hayes wire strainer, still used, to the specialised Fletcher top-dressing aircraft designed and manufactured in Hamilton. Civil works to improve farming include, for example, major 1920s dredging works on the Hauraki and Rangitikei Plains to establish drainage and transform them into prime dairy production areas. The term *engineering* heritage can be broadly considered the same as *industrial* heritage.

10. REFERENCES:

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Comment: François LeBlanc was Head of Field Projects for the Getty Conservation Institute, Los Angeles. He presented at the 2007 Workshop on the Management and Conservation of World Heritage Sites, hosted by UNITAR (United Nations Institute for Training & Research) in Hiroshima.

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Mahoney P, 2009 *Industrial Heritage in NZ*: lecture to heritage management post-graduate students, Victoria University, Wellington

Mahoney P, 2009 (paper in preparation) *The KTC Great Barrier Tramway: An Outstanding Railway Incline Achievement,* Department of Conservation, Wellington

National Film Unit productions, the Weekly Review and successor black & white film programs; held by Archives New Zealand in Wellington; find on Ziln, NZ's first on-line TV channel, www.ziln.co.nz.
Comment: Weekly Review was a 10-minute program offering two or three stories, many with an engineering heritage element. It became a 20-minute program renamed Pictorial Parade. Some programs had a single subject such as the brilliant record of the Denniston Incline just before it was closed (Parade no. 195). All programs are now available on-line in sufficient quality to enable assessment of potential audiovisual use.

Perrett T, 1982, *Managing the Otago Goldfields Park,* DOC, Dunedin, find at www.doc.govt.nz, keywords: Otago Goldfields.
Comment: This paper, first published in the 1984 'New Zealand's Industrial Past', set out a comprehensive thematic approach to heritage management.

Te Ara, Bush Transport, contributed by Paul Mahoney; find at www.teara.govt.nz, keywords: bush tram

Thornton G, 1982, *New Zealand's Industrial Heritage,* Reed, Wellington.
Comment: This book provided the first comprehensive overview of NZ's industrial and engineering heritage and is a major reference work.

Tourism NZ, 2003, *Demand for Cultural Tourism Research,* by Colmar Brunton, find at www.tourisminfo.co.nz, keywords: demand cultural tourism research

11. APPENDIX 1: BRINGING HERITAGE TO LIFE

Engineering heritage audiovisuals by Tom Williamson:

- New Zealand Flax - A Fortunate Fibre
- Bottled Lightning: *an astonishingly early hydro-electric power station at Reefton*
- Dawson Falls: *the earliest General Electric dynamo working outside the USA*
- The Lyttelton Timeball Station: *the importance of time explained, in establishing 'place'*
- The Last Voyage of the Edwin Fox: *an immigrant ship now the 9th oldest surviving ship in the world*

These programs are available from Tom Williamson

Custom work on Department of Conservation sites:

- Kaiarara Dam (Great Barrier Island)
- Woodstock Gold Mine (Karangahake)
- Golden Gateway (the Karangahake Gorge railway)
- Big River Gold Mine (near Reefton)

12. APPENDIX 2: FINDING KEY PLACES

Find information on heritage places referred by searching their names in Google NZ:

Dunedin Gasworks Museum
Dawson Falls Power Station, Taranaki
Caterpillar Museum, Rotorua
Edwin Fox, Picton
Ferrymead Museum, Christchurch
Golden Point Stamper Battery, Otago
Great Barrier Island Tramway
Hayes Engineering Works, Otago
Kauri Museum, Matakohe, Northland
MOTAT, Auckland
Ormondville Railway Station, Hawkes Bay
Otago Central Rail Trail
Shantytown Sawmill, West Coast
Tawhiti Museum, Hawera
Totara Estate, Otago

Queensland's timber and iron lighthouses: 19th century colonial innovation.

Peter Marquis-Kyle, conservation architect, Brisbane

SUMMARY: *The geography, resources and economic circumstances of the colony of Queensland fostered the local design and construction of two related types of composite timber-framed, iron-clad lighthouse towers in Queensland from the 1870s – an early type clad with riveted wrought iron plating, and a later type clad with corrugated galvanised iron. This paper gives a short historical account of their design and construction, outlines the range of towers and how they have been changed. The paper concludes with an assessment of the success and influence of the type, and a table of major 19th century lighthouses.*

1. INTRODUCTION

From the establishment of the colony of Queensland in 1859 until the separate colonies federated to form the Commonwealth of Australia in 1901 engineers and architects designed an impressive set of lighthouses. The Queenslanders developed a type of timber framed, iron plated lighthouse tower which is a local Queensland invention. It turned out to be a technical and economic success, though the idea was not taken up elsewhere.

Figure 1. *Queensland coastal lighthouses before 1900*

I am an architect and I specialise in the conservation of historic buildings and places. I was commissioned in 2006 to work on a condition survey of 58 heritage listed lighthouses for the Australian Maritime Safety Authority (AMSA). My client was Australian Maritime Systems Ltd, AMSA's navigation aids maintenance contractor. I visited all but one of these lighthouses myself, a wonderful experience. The oldest of these structures was built in 1845, the youngest in 1984.[1] As a group they represented many aspects of the history of Australian lighthouse design, and the local variations that arose in response to the circumstances in each of the Australian colonies. This experience awoke my interest in the story of the composite timber and iron lighthouses that are the subject of this paper.

2. THE FIRST QUEENSLAND LIGHTHOUSES: LOCAL STONE AND IMPORTED CAST IRON

The new colony of Queensland, when it separated from New South Wales in 1859, started out with no railways and only a few poor tracks. It depended on coastal shipping, despite the difficulties of navigating a hazardous coast. It inherited a single lighthouse, at Cape Moreton, a stone tower built by convict stone masons and labourers in 1857 using sandstone quarried on the site.[2]

One of the first appointments made by the new colonial government was a marine surveyor, Captain George Poynter Heath. From his appointment in 1859 to his retirement in 1887 Heath was responsible for supervising the opening of 13 new ports, establishing 33 lighthouses, 6 lightships and 150 small lights and marking 724 km of the inner route through the Great Barrier Reef. Captain Heath advised a parliamentary select committee that set out the beginnings of the policy for developing lighthouses along the Queensland coast.[3]

Queensland's 7,000 km mainland coastline with its capes, shoals, shifting sand spits, tides and other navigation hazards, sits behind the 350,000 km^2 Great Barrier Reef – a complex of islands, cays and reefs. The coastline is not well provided with suitable stone for building traditional lighthouse towers.

In 1864 the select committee recommended erecting lighthouses at Sandy Cape and Bustard Head. Selection of these two sites reflected the importance at that time of the ports of Maryborough and Rockhampton. The government acted, and its agents in England procured two complete lighthouses in 'kit' form, with towers of cast iron segments made to be bolted together on their sites. The two towers were manufactured by different foundries in England, though their designs were similar. The Bustard Head tower was cast by Hennet & Spink of Bridgwater in Somerset, and the Sandy Cape tower by Kitson & Co of Leeds in West Yorkshire. Both were equipped with lantern houses and optical apparatus manufactured by Chance Brothers & Co of Smethwick near Birmingham, the major English lighthouse equipment maker. The Bustard Head lighthouse was first lit in 1868, and Sandy Cape in 1870. These fully-imported cast iron lighthouses were effective, though costly.[4]

The two cast iron lighthouses were erected by private building contractors under the supervision of officers of the Department of Public Works and with the advice of the Portmaster. The contractors also built timber houses for the light keepers. Erecting the iron lighthouses was quick, but getting the lighthouse components and other materials to the sites and preparing concrete bases beforehand took many months. The departmental staff and the contractors learned some useful lessons about the best ways to organise the works – lessons they would later apply to other lighthouse projects.

Figure 2. *The cast iron plates of the Bustard Head lighthouse tower*

3. THE EARLY TIMBER TOWERS

Even before the cast iron lighthouses were erected, the government had begun building small lighthouses to guide mariners at port entrances. These were timber framed and sheeted towers, generally square or hexagonal in plan. A lighthouse of this kind, built in 1866 at Cleveland Point, still survives.[5] On Woody Island there is a leading pair of lighthouses marking the line of a channel approaching the entrance to the Mary River, also dating from 1866.[6]

These timber towers – with their hardwood frames, truncated pyramidal forms, and horizontal weatherboard sheeting – were similar to New Zealand lighthouses designed by John Blackett through the 1870s and 1880s.[7] Blackett acknowledged North American precedents for such forms, and there may have been American influences on the Queensland designs too. While Blackett was refining the design of timber lighthouse towers to improve stiffness, wind resistance and durability, the Queensland designers were finding different ways to deal with these problems.

Figure 3. *Burnett Heads lighthouse*
(photo: Bundaberg Regional Council collection)

4. THE PROTOTYPE TIMBER-FRAMED, IRON-PLATED TOWER: LADY ELLIOT ISLAND

Lady Elliot Island lighthouse, first lit in 1873, marked the beginning of a new system for building larger coastal or landfall lights with timber frames. The designer was Robert Ferguson (1840-1906), at that time a District Foreman of Works attached to the office of the architect F D G Stanley, Superintendent of Public Buildings.

Ferguson already had some lighthouse experience – he wrote the specifications and oversaw the erection of the iron lighthouses at Bustard Head and Sandy Cape, and was probably responsible for the 1866 timber towers on Woody Island. Ferguson was a skilled, innovative and practical architect who was later responsible for the standardised design of a series of many timber school buildings.[8]

For Lady Elliot Island, Robert Ferguson developed a composite form of construction, which combined the economy of timber framing with the weather-tightness and durability of iron plating. This design brought together the established materials and techniques of timber-framing and boiler-making. The components of the tower were pre-fabricated on the mainland, shipped to the island, and assembled there.

The lighthouse tower was round in plan and tapered in profile, forming a truncated cone. The battered outer walls were framed with sawn hardwood posts and rails bolted together, with joints reinforced with wrought iron straps and brackets. The walls had light timber braces which would have served to stabilise the timber structure before the iron shell was fitted. There were three intermediate floors with hardwood joists and pine floor boards. In the centre of the tower was a vertical timber weight tube, which formed a central support for a winding timber stair that climbed up the bottom three levels of the tower. On the fourth level, where the conical tower was too small to fit a stair, there was a fixed ladder up to the level of the light room and balcony.

The frame was supported at the bottom by a segmented cast iron ring that formed a base, bolted down to a massive concrete footing and floor cast within a low stone wall. The timber posts were bolted to lugs made as part of the iron ring.

The tower was clad with a covering of galvanised wrought iron plates, about 2.5 mm thick, which were rolled to the conical shape. Joints between the plates were lapped and riveted, and the plating was screwed to the timber framework and to the iron ring at the base. A timber door was fitted at the bottom of the tower, and glazed windows at each floor level.

At the top of the tower was a timber framed structure which formed the floor of the lantern room and the projecting balcony surrounding the lantern. This balcony floor had a flooring of timber boards with a waterproof covering of lead sheet. On this floor was assembled a hexagonal lantern room with a domed roof, all constructed by the building contractor – this was probably done to save the cost of an expensive imported prefabricated lantern. Inside the lantern was a typical Chance Brothers 4th order (250 mm focal radius) rotating optical apparatus with kerosene (paraffin) wick burner and weight-driven clockwork.

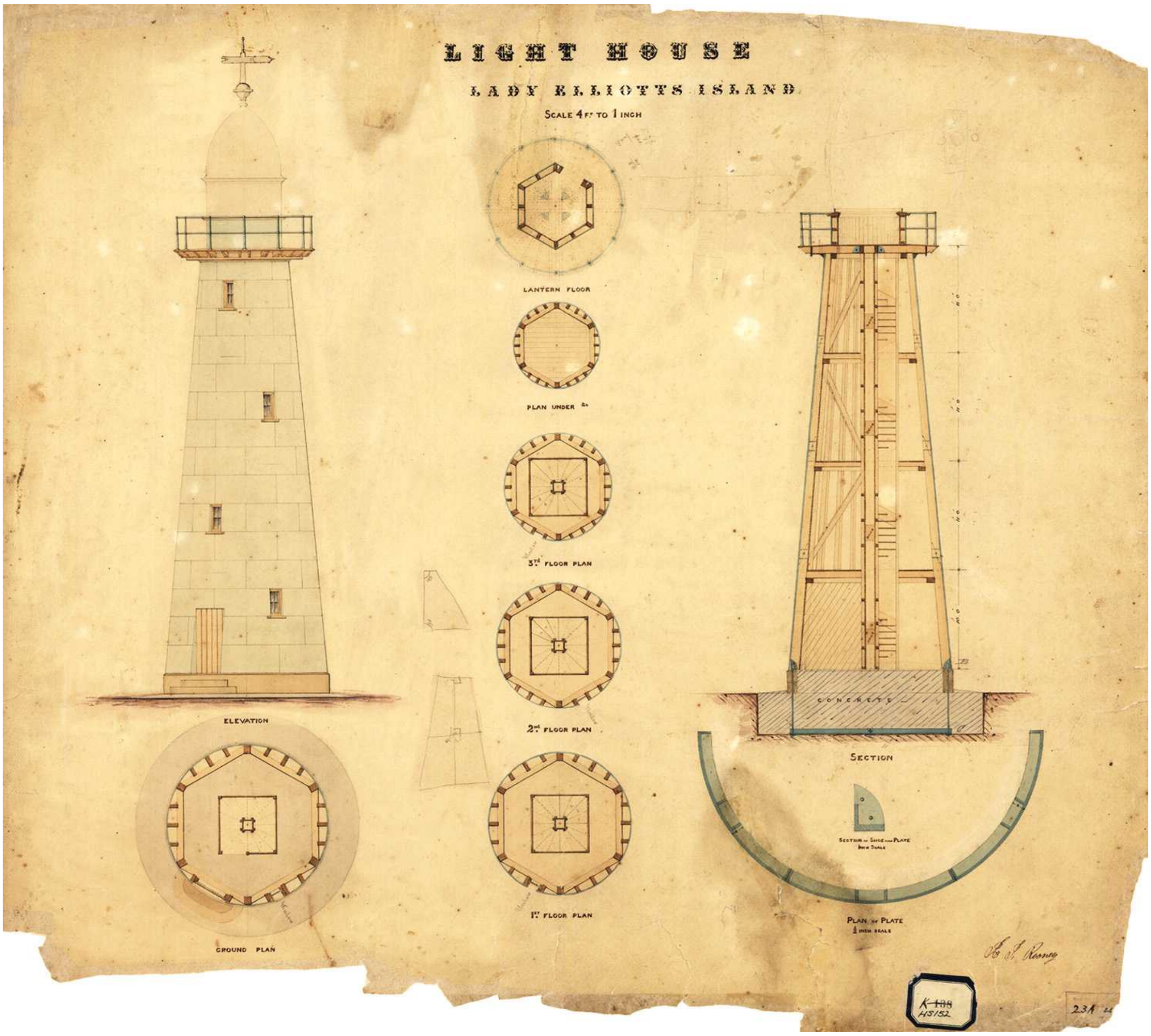

Figure 4. *One of the contract drawings for the construction of the Lady Elliot Island lighthouse*

Some of the main benefits of this design were nicely argued by F D G Stanley in a report to the government:

On connection with the Tower, as to construction and material, I would beg to remark that while the present design is more costly than the original, which was similar to those erected on Woody Island and entirely of timber, it is submitted that the increased strength and durability gained by using boiler plate casing, concrete foundation etc. will eventually more than compensate for the greater outlay in the first instance, the shrinkage and decay of timber sheeting in exposed situations such as the Lighthouse will occupy, being so great, as to render it almost impossible to keep the buildings weatherproof. Added to this the destruction caused by the white ant to all timbers placed below or upon the ground, is such as to render it most desirable, that every means should be used to place timber framing as far as possible beyond their reach.[9]

Stanley did not mention the structural benefits of the design, in particular the resistance to wind loads provided by the timber frame, the iron shell, the cast iron ring and the concrete base, all of which were strongly connected. In a region subject to regular cyclones this was important.

5. A SERIES OF TOWERS

After the Lady Elliot Island lighthouse was satisfactorily completed in 1873, eleven more of the same basic type were built – the last at Booby Island in the Torres Strait in 1890. The attributes of the sites were varied, but most were remote and difficult to access. Some of the sites were on coral cays or sand spits that required tall towers, and some were on rocky capes or islands where shorter towers would do. They were all equipped with Chance Brothers optical apparatus, ranging in scale from 2nd order (700 mm focal radius) to 4th order (250 mm focal radius).

The height of each tower was determined in response to the elevation of each site, and the range required. The shortest of the towers (Flat Top Island) was just 6 m from the ground to the lantern floor, and the tallest (North Reef) was 24 m. The details and materials were refined as the series evolved, but the basic structural system established at Lady Elliot Island was retained.

6. NORTH REEF

The most remarkable of the series was North Reef Lighthouse, and not only because it was the tallest. This lighthouse, completed in 1878, is an important aid to navigation along the Great Barrier Reef, built on a small migratory patch of sand inside a fringing coral reef. There was no stable ground available to build houses for the lighthouse keepers and their families, so minimal keepers' quarters were incorporated in the lighthouse tower. It operated as a 'bachelor' lightstation, staffed by keepers without families.

The tower sits on a cylindrical caisson of cast iron segments bolted together, sunk below low water onto a foundation of coral, and filled with concrete. This iron and concrete base is 13 m in diameter and 4.6 m high, with voids formed inside the mass of concrete for storage of fresh water. The tower was originally surrounded by the sand island, but the island later migrated away from the tower, leaving the lighthouse surrounded by water. It is now again surrounded by sand.

The 24 m high main tower was generally similar to that at Lady Elliot Island, but on a larger scale. There were four intermediate floor levels, and the optical apparatus was of the 2nd order. Apart from the iron and concrete base the most unusual aspect of the structure was the ring of rooms around the base of the tower. Here were the keepers' quarters, comprised of three bed rooms, two kitchens, two sitting rooms, and a store room – perhaps the head keeper had a private kitchen and sitting room, and the two assistant keepers had to share. The keepers quarters were framed and lined with timber, with a roof covering of galvanised iron with rolled seams, and external wall sheeting of corrugated galvanised iron.

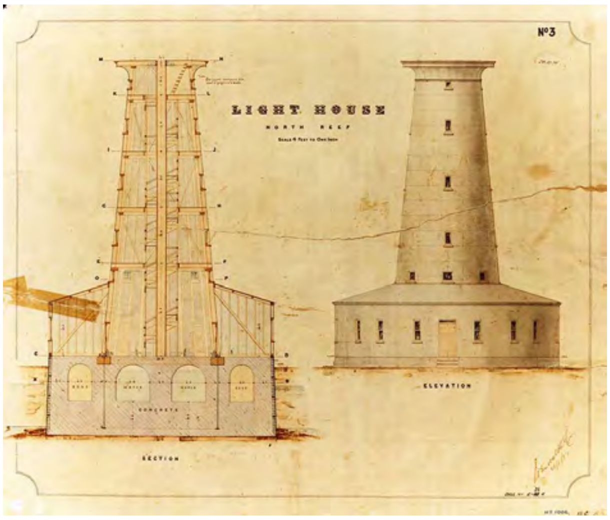

Figure 5. *North Reef lighthouse, 1878*

7. A LOWER COST VARIANT: CORRUGATED IRON CLADDING

In the 1880s a variant design was introduced for shorter towers, with corrugated galvanised iron sheeting instead of the thicker boiler plate. The first of this type was built at Goods Island in the Torres Strait. The timber framework had heavy timber cross bracing, but was otherwise similar to the iron plated type. The sheeting was specially formed with tapering corrugations to suit the conical shape of the tower.

4

Figure 6. *Interior of Goods Island lighthouse*

8. LOSING REGIONAL VARIATION: THE COMMONWEALTH LIGHTHOUSE SERVICE

Coastal navigation aids became a commonwealth responsibility after federation, but it took a few years to integrate the separate colonial lighthouse services into a new Commonwealth Lighthouse Service and to transfer the colonial assets to it. By 1912 the new arrangements were in place, and work began to upgrade lighthouses and build new ones. The new lighthouses were designed in a central office in Melbourne, and the distinctive character of the various colonial lighthouse services faded. The timber and iron towers in Queensland were kept in service, and their equipment upgraded, but no new towers of the distinctive Queensland type were built.

After 1912 new major Australian lighthouse towers, everywhere around the country, were built of reinforced concrete or steel lattice frame construction.

9. NEW TECHNOLOGY IN OLD TOWERS

Through the 19th and 20th centuries the lighthouse equipment was upgraded as improved equipment was developed. From about 1900 wick burners were replaced by pressurised incandescent burners, bringing substantial increases in brightness and efficiency, a process that gained momentum after the Commonwealth Lighthouse Service took over. Rotating lenses were mounted on mercury float bearings, more reliable and efficient than the previous generation of roller bearings. Some of the early lantern rooms were replaced by new Chance Brothers lanterns in the 1920s. From 1913 automatic acetylene apparatus – including the sun valves, flashers and rotating pedestals patented by Gustav Dalén's and produced by the AGA company – were introduced. More recently, electric lighting has taken over, generally using solar powered Vega VRB-25 apparatus made in New Zealand.

The most significant change to the lightstations has been their complete automation and de-manning. The last manned lighthouse in Queensland was automated, and the keepers withdrawn, in the 1990s.[10]

The nineteenth century towers have accommodated major changes to the optical and lighting equipment, without requiring substantial change to the towers.

10. A SUCCESSFUL DESIGN, BUT A DEAD END?

Of the twelve timber framed lighthouse towers with riveted iron plating built between 1873 and 1890, ten still survive. Six remain in service as major coastal or landfall navigation aids (Low Isles, North Reef, Cape Cleveland, Dent Island, Double Island Point, Booby Island). Two have been dismantled, moved and re-erected in museum settings (Cape Bowling Green and Pine Islet). Two more are no longer operating, but are conserved in situ (Lady Elliot Island and Flat Top Island).

The statistics for the corrugated iron towers are similar. Of the four examples listed in the table, two are in service (Goods Island and Grassy Hill) and the other two have been conserved – one in a museum (Bay Rock) and the other returned to its original site (Caloundra).

For most of their operating life these towers were well maintained by the resident keepers, and by itinerant tradesmen brought to the stations several times each year by the lighthouse steamers and tenders. Since de-manning, the towers have been maintained by periodic visits by Transport Department staff or, more recently, by the maintenance contracting company which commissioned my survey in 2006. The main task has been the maintenance of the paint which protects the iron plating.

North Reef lighthouse has been unmanned since 1978, and received periodic flying visits from technicians. It is due for major maintenance, which AMSA is planning to undertake. The other operating towers are all in good condition. They demonstrate the quality of their original design and construction, and more than a hundred years of timely care. Altogether the lighthouse towers have performed well, and have justified F D G Stanley's confidence in the durability and long-term value of the form of construction.

But, despite their innovative design, they appear to have had no influence outside of Queensland – they are, perhaps, an evolutionary dead end.

11. REFERENCES

See below

12. APPENDIX – TABLE OF MAJOR 19TH CENTURY QUEENSLAND LIGHTHOUSES

Lighthouse	*Year*	*Height*	*Order*	*Cost of buildings*	*Cost of optical apparatus*	*Structure*	*Extant*	*Moved to*	*In service*
Cape Moreton	1857	21 m	1st, catoptric	£15,232	included	stone	yes	-	yes
Bustard Head	1868	10 m	2nd	£4,835	£2,124	cast iron	yes		yes
Sandy Cape	1870	30 m	1st	£12,000	£3,000	cast iron	yes		yes
Lady Elliott Island	1873	17 m	4th	£1,820	£263	timber frame, iron plating	yes	-	no
Cape Bowling Green	1874	16 m	3rd	?	?	timber frame, iron plating	yes	Sydney	no
Cape Capricorn	1875	7 m	3rd	£3,938	£1,295	timber frame, iron plating	no	-	no
Low Isles	1878	18 m	3rd	£4,090	£1,389	timber frame, iron plating	yes	-	yes
North Reef	1878	24 m	2nd	£9,208	£2,359	timber frame, iron plating	yes	-	yes
Cape Cleveland	1879	11 m	4th	£2,635	£514	timber frame, iron plating	yes	-	yes
Dent Island	1879	10 m	4th	£2,558	£592	timber frame, iron plating	yes	-	yes
Flat Top Island	1879	6 m	4th	?	?	timber frame, iron plating	yes	-	no
Archer Point	1883	9 m	?	?	?	timber frame, iron plating	no	-	no
Double Island Point	1884	12 m	3rd	£3,556	£1,533	timber frame, iron plating	yes	-	yes
Pine Islet	1885	11 m	2nd	£4,540	£2,345	timber frame, iron plating	yes	Mackay	no
Goods Island	1886	5 m	4th, fixed	£2,406	£165	timber frame, corrugated iron sheeting	yes	-	yes
Grassy Hill	1886	6 m	4th, fixed	£842	£156	timber frame, corrugated iron sheeting	yes	-	yes
Bay Rock	1886	8 m	4th, fixed	?	?	timber frame, corrugated iron sheeting	yes	Towns-ville	no
Booby Island	1890	18 m	2nd	£4,244	£2,321	timber frame, iron plating	yes	-	yes
Caloundra	1896	9 m	?	?	?	timber frame, corrugated iron sheeting	yes	old site	no

[1] The best general published history of Australian lighthouses (now out of date and out of print) is Reid, Gordon 1988, *From dusk till dawn: a history of Australian lighthouses*, Macmillan, Adelaide.

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[2] For an account of Queensland lighthouses before 1900 see Thorburn, J H 1967, 'Major lighthouses of Queensland, part 1', *Queensland Heritage*, vol 1, no 6, May 1967 & 'part 2', *Queensland heritage*, vol 1, no 7, November 1967.

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[4] Buchanan, Stuart 1999, *Lighthouse of tragedy: the story of Bustard Head Lighthouse: Queensland's first coast light*, Coral Coast Publications, Samford. See also Thorburn, 'Major lighthouses of Queensland, part 1.'

[5] Queensland Heritage Register Entry, http://www.epa.qld.gov.au/chims/placeDetail.html;?siteId=15547

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3rd Australasian Engineering Heritage Conference 2009

There's Naught to Fear for the Port of Oamaru

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SUMMARY: *Because the sea was the main highway for New Zealand's colonial towns, aspiring centres that lacked natural harbours had to build artificial ports. Oamaru faced severe financial and engineering challenges, but with the aid of 'Moa', the largest full-slewing rail-mounted travelling steam crane in the world, it completed its breakwater in 1884, offering safe berthage for UK-trade meat ships. The port saw its last ship in 1974, just ahead of the container age, bequeathing us the country's best-preserved Victorian/Edwardian harbour: a concrete breakwater, completed in 1884, three concrete wharves completed between 1875 and 1879, and two wooden wharves completed in 1884 and 1907 respectively. This paper examines the history of the port and its engineering legacy.*

In the mid-1850s a small settlement grew up in the lee of Cape Wanbrow in North Otago to supply sheep stations.[1] The Cape afforded the Oamaru anchorage some protection from southerly winds but was completely exposed to the prevailing north-easterlies. The small vessels lying off the beach had to load and discharge in the open sea using surf boats. It was slow, clumsy, expensive and dangerous – ships played Oamaru roulette.

Despite that, Oamaru boomed, quickly becoming Otago's second-largest settlement. But the Otago Provincial Government had little money to spend on port development and in any case its harbourmaster preferred Moeraki to Oamaru as North Otago's port and was not shy when it came to expressing his preferences: 'sums expended in making Harbors where nature has not already provided them would be a needless expenditure', he declared.[2] A small derrick was provided to haul goods up from the beach to the provincial government's new warehouse in 1858, followed shortly afterwards by a flagstaff and some moorings out in the bay, but that was all.

Figure 1. The Oamaru landing service site ca 1870. – North Otago Museum 5795

It was not long before the exposed beach started claiming ships and lives. In 1860 the small schooner *Oamaru Lass* went ashore. She was recovered, but an increasing number of ships were not.[3] Insurance rates soared. In 1866, after much controversy, the provincial government authorised an iron-piled L-shaped jetty to be built near the end of Cape Wanbrow to a design by J.M. Balfour. It was ready by late 1867.

Unfortunately, the jetty was unprotected by any breakwater or seawall. In February 1868 a massive storm sank two overseas wool ships and a coaster and left the outward end of the jetty a mangled ruin. For Oamaru it was back to square one.

While the provincial harbourmaster still wanted to link Oamaru to Moeraki by rail, locals demanded their own port and persuaded the provincial government to commission engineers Edward Dobson and John Blackett to report on port options. After dismissing a deepwater port in the bay, they recommended building a small wet dock in the Brewery Lagoon capable of handling coastal vessels of up to 300 tons and drawing no more than 2.7m. The dock would be protected by long seawalls running out from the end of the Cape (450m long), approximately near the remaining 25m stump of the old jetty, and (150m) just north of the edge of the Oamaru creek, which flowed into the lagoon. Lock gates would have guarded the entrance to the basin, and sluices in the creek would have released water periodically to flush away any shingle that accumulated at the entrance.[4]

The Oamaru Dock Trust struggled badly. After Dobson and Blackett refused to oversee the project, Dobson attacked Otago Provincial Chief Engineer George Barr's plans. The Dock Trust then hired David Balfour, who drowned off Timaru, leaving John McGregor to supervise the work. Although contractors Walkem & Peyman started building concrete blocks for the south-east seawall early in 1871, money shortages forced the Dock Trust to concentrate on the south-east seawall at the Cape and to delay the wet dock. This proved a blessing in disguise, since the expensive dock if built might have doomed Oamaru to handling feeder services only. The 1870s were a time of rapid ship size growth. The Harbour Company's steamer *Maori*, a regular trader between Dunedin and Oamaru in the 1870s, was 171 grt (gross registered tons).[5] The Union Company's *Hawea* of 1875 was 720 grt. None of the small-ship harbours between Oamaru and Port Chalmers/Dunedin – Kakanui, Moeraki, Shag Point and Karitane – would survive the 1880s as trading ports.

Walkhem & Peyman learned as they went along. At the Point, where a reef ran out a short distance, they built the first section (240m long) of the breakwater with a rubble-filled cavity between two rows of 4-high concrete blocks. As the wave action increased the further out they went, they changed to solid concrete block construction.[6] Concrete, although expensive, was essential since the rock from the quarry at the foot of the breakwater was too weak to withstand the sea; the cement was imported from Britain in casks and mixed on site. This area was originally very cramped, but it was made more practical by several small reclamations.

The early work was done by manual labour but the contractors had ordered a massive rail-mounted steam travelling crane from Dunedin engineering firm Kincaid, McQueen & Co. Described as a 'derrick crane', the 'Moa' was built of wrought and cast iron.[7] The overhang of the jib was 7.5m and the counterweight was mounted at the back end of the upper frame with square cast iron blocks fitted in between the girders, with water tanks above. The tanks were filled only when the heaviest weights were being lifted. In July 1873 the crane successfully lifted a 30-ton [27.2 tonnes] load of iron rails at the Dunedin factory. The contract price was £1,600 [ca $192,000 in 2009 values].[8]

Figure 2: The steam crane 'Moa' working in deteriorating weather conditions. – North Otago Museum 4058

The crane worked well and was a source of deep pride to colonial boosters. It has often been described as second only to one at Madras. In late 2008, however, Bruce Ward from the Historical Crane Society confirmed that the Madras crane was not only a later machine, but it was smaller. 'The Oamaru crane was clearly the largest full-slewing rail-mounted steam crane capable of travelling with a rated load anywhere in the world. All other large rail-mounted cranes had less reach and less lifting capacity that the Kincaid McQueen crane for at least 10 years after Oamaru.'[9]

Contracts for construction were let out in stages. Work was periodically delayed by shortages of cement or (more frequently) by bad weather. Needless to say, progress slowed the further the breakwater advanced out from the Cape as the water got deeper and the seas rougher. Divers were used to help with smoothing the seabed where the blocks were to be placed.

The trickiest part of the job was sinking the four caissons that formed the seaward end of the breakwater. The contractors built four large wooden caissons, three of them 7.62m long and 5.18m wide. These were floated out to the end of the breakwater, filled with 600-700 tonnes of concrete and then bound together with a concrete cap to 'constitute an impregnable head to the breakwater.'[10] The seabed that would form the resting place for the monoliths first had to be dredged and flattened.

Completing the end was a lengthy job. The first caisson was floated out in December 1882. The plan was to sink it in January 1883 but that year was an unusually stormy one, and since perfectly calm conditions were required for aligning and sinking the caissons, it was February 1884 before the last one was in place.

Figure 3: Early in 1883. A couple of surf boats are at the end of the breakwater and a wooden caisson is being towed along Macandrew Wharf to be sunk to form part of the breakwater tip. Another caisson is taking shape behind the Cross Wharf in the background. – North Otago Museum 4050

The Moa's final fate is unknown. A scathing attack on the Oamaru Harbour Board (which had replaced the Dock Trust in 1874) in the *Otago Witness* in May 1908 described 'a big steam crane that lies desolately rusting at the [presumably landward] end of the breakwater.'

2

As the breakwater advanced out into the bay, the Harbour Board began building wharves. The first, the 46m-long Macandrew Wharf, was completed against the landward end of the breakwater in 1875. Next year the wharf was extended to 100m and the 1875 section was widened slightly to improve operations for the Harbour Board's steam cargo cranes. For passengers on the two ferries running between Dunedin and Oamaru, being able to step on to a secure wharf was a welcome improvement on bobbing about in the old surfboats.

The next two wharves, Normanby Wharf (1878) and the short Cross Wharf (1879) running most of the way between Normanby and the breakwater, were like Macandrew Wharf, built of concrete. Their completion gave Oamaru 370m of sheltered berths. Above all, it also made it a much safer and cheaper port for merchants. With the completion of Macandrew Wharf, shipping accidents, which had made the port notorious, virtually ended. The only ships still unable to use the town's wharves were the large overseas ships that loaded wool for London.

That was about to change. In 1879 the port's prospects were improved immeasurably when Thomas Forrester made some trial bores in the bay and discovered that the seabed was not solid rock, as had been thought, but compacted shell and mud. It was tough, but it could be dredged. Forrester's discovery was a turning point for town and port. With enough money, the harbour could be dredged and made into a deepwater export port. The big ships would no longer have to moor off the breakwater.

Forrester is today best remembered as the architect from the partnership Forrester & Lemon, many of whose Oamaru Stone buildings are registered historic places. For 31 years, however, his day job was secretary/engineer to the Oamaru Harbour Board and it was this contribution that was crucial to the town's prosperity.

The harbour board, its funds shrinking as the breakwater advanced into the bay, was deeply divided. Some wanted to economise but after considerable debate the majority voted to build a deepwater port capable of handling direct shipping from Britain. The main components of this plan would include a steam dredge (1883), a large export wharf (Sumpter Wharf, completed in 1884) and a long rubble mole at the northern end of the harbour to protect moored shipping from sea surge. The mole was halted in September 1884 at a length of 489.5 m along the top – about 60 m short of the length originally planned and without the elaborate concrete tip envisaged. Completion had been delayed by the low quality of the soft rock from the board's quarry. It fragmented badly during blasting and much had to be rejected as too small to withstand the waves.

Figure 4: Two wool ships and a trans-Tasman steamer lie alongside Sumpter Wharf, the export pier completed in 1884. – North Otago Museum 280

1884 was a busy time for the port. The dredge *Progress*, assembled the previous year from components built in Britain, busied herself dredging the entrance channel, swinging basin and the berths alongside Sumpter Wharf, a wooden wharf connected to the shore by an elegant curved pier. Sumpter Wharf was designed to service the largest ships trading between New Zealand and the United Kingdom. In August 1884 its first user was the sailing ship *Dunedin*, which had taken the historic first shipment of frozen meat from Port Chalmers to London three years earlier. The second caller was the *Elderslie*, more than twice the *Dunedin*'s size, the first frozen meat steamer for the New Zealand trade and initially intended to trade solely between Oamaru and London. The Port of Oamaru had stolen a march on its rivals.

A newspaper from the rival town of Timaru was impressed: 'A breakwater with a mole at the end of it, a wharf with a big hole dredged alongside, and what is more satisfactory. A big steamer lying in the big hole, loading up a huge cargo of mutton: all these things indicate progress, show a spirit of enterprise and auger well for the future prosperity of Oamaru.'[11] An Oamaruvian went one better (or worse?) by composing triumphant doggerel which included the chorus:

'Oamaru, fair Oamaru; The Port of Oamaru;
We tell you here there's nought to fear
For the port of Oamaru.'

The newspaper reports, that song, they all underline the importance that colonists attached to keeping up with their rivals. Oamaru was one of James Belich's 'protein ports': 'Oamaru duelled indecisively with Timaru in the 1880s, with the two freely duplicating each other's expensive harbour works in a "notorious instance" of the costs of small-town rivalry', he noted. 'But whatever the long-term costs, in the short term two sets of port facilities created twice the progress, in jobs and business.'[12]

Ironically, by the time the breakwater was finally capped off and Sumpter Wharf was lined with ships, the local economy had nose-dived. The progress business was put on ice. For some time the Long Depression had been settling over the colony and Oamaru's growth spurt came to a sudden stop virtually at the same time as the mole, breakwater and Sumpter Wharf were finished and the grandest of the Harbour/Tyne Street precinct grain stores opened their doors. The town's population would not regain its 1881 level until the 1920s.

What caused the real pain for the Oamaru Harbour Board was a combination of the depression, the loss of some short-sea coastal trade to the new South Island Main Trunk railway (1878/9) and damage to the breakwater. The historic Dunedin-Oamaru trade fizzled out in 1891, although the carriage of coal for locomotives (Oamaru was a major station on the Main Trunk network) may have made up for its loss. The damage to the breakwater was a bigger blow. In August 1886 a massive storm punched a 100-metre gap in the structure near its outer end. It would cost £8,000 to repair and another £22,000 for the seaward armouring dropped earlier in an economy now seen as false.

Figure 5: A heavy sea strikes the breakwater. The low-lying structure was repeatedly damaged by storms. – North Otago Museum 294

Harbour boards financed themselves through a mixture of port charges, rental income from endowments and from levying ratepayers. Rating was always a particularly sensitive issue, so only after considerable debate were repairs authorised; they were carried out successfully over 1888/9. A year later the colony-wide Maritime Strike broke out. The employers won that dispute, but the loss of revenue, coming on top of mounting interest bills, was enough to tip the Oamaru Harbour Board over the edge. Late in 1891 it defaulted on interest payments due to London investors. By 1885 it had spent £280,000 on capital works – over $46 million in 2009 terms, over 80 per cent of that borrowed, much from Britain. A receiver was appointed and the strictest economies were implemented. The dredge spent much of its time either laid up or chartered out to other harbour boards.

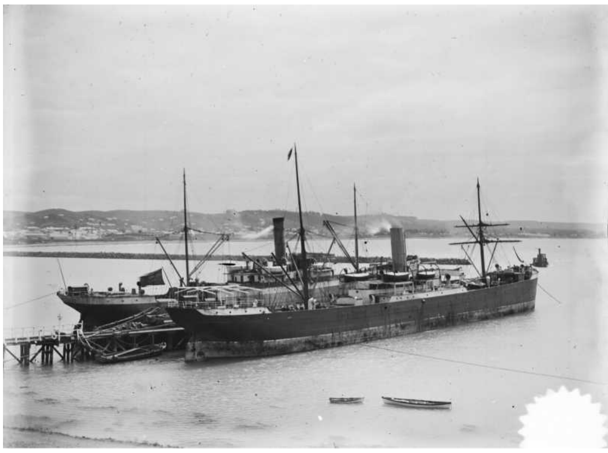

Figure 6: An unknown tramp steamer (left) and the Home boat *Tekoa* lie alongside Sumpter Wharf during the South African War. Ships this size were beginning to tax the wharf. – North Otago Museum 2377

In 1900-2 the port received a welcome boost from the South African War as tramp steamers arrived to load grain. In fact the port's trade was quite brisk and it was really debt servicing that was dragging it down. That and the perennial problem of ship size growth. By the early 1900s the last of the old sailing ships had been taken off the NZ-UK run and even the first steamers of the mid-1880s were being replaced by larger ships too long to berth safely in high winds against Sumpter Wharf. In 1903 the 151-m-long freighter *Essex* bypassed the port and the harbour master imposed a length limit of 121.9 m on ships using the wharf.

While Sumpter Wharf could have been extended and strengthened for £4,000, the Harbour Board opted for building a new wharf on top of the mole. This could handle the biggest new overseas ships, while still leaving Sumpter free for smaller overseas, trans-Tasman and coastal vessels. Although the board was still in receivership, the court accepted that the new wharf would enable the port to trade its way out of receivership faster. It authorised spending £10,000 on the new wharf and associated dredging.

In 1906 contractors Fitzgerald & Bignell started work on the new wharf, named Holmes after the board chairman and had the initial section, 152 m long, ready by the middle of the following year. The first ship to use it, the *Waiwera*, was 6,237 grt, more than 1,000 tons more than previous callers. The port was once again in the front ranks of the export trade, able to handle all but a handful of the very biggest passenger/cargo steamers.

The port lost its UK trade for a few years during and immediately after the First World War because of wartime centralisation, but lobbying by the Harbour Board saw services restored in the early 1920s. The interwar years saw ever-larger 'Home boats', as the UK trade ships were called, visiting the port, culminating in the 1938/39 calls by the 10,100-ton new generation motor vessels *Opawa* and *Otaio*, ships nearly ten times the size of the UK trade ships when the harbour works were planned in the 1870s. To accommodate such vessels, the Harbour Board extended the landward end of Holmes Wharf. Sumpter Wharf now handled less than 10 per cent of the port's cargo, but because a big ship completely tied up Holmes Wharf, the board also widened and modified Sumpter to serve coastal and trans-Tasman ships when a Home boat was in port.

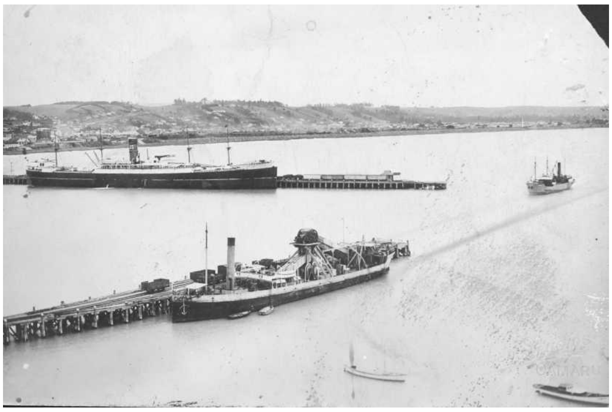

Figure 7: An interwar photograph showing the 9,512-ton Home boat *Westmoreland* at Holmes Wharf, built on the mole in 1917. The coaster *Holmdale* is approaching Sumpter Wharf. – North Otago Museum 2550

The Harbour Board's major programme, however, was a breakwater extension. Because the alignment of the breakwater against a coastline that curved out towards its tip ruled out a simple lengthening of the seawall, it was planned to build an extension at an angle approximately two-thirds along the length of the breakwater. This would provide protection for dredges maintaining the shipping channel out to deeper water. In 1914 Lyttelton engineer Cyrus Williams had prepared just such a plan for a 533-m arm, but a shortage of funds had prevented the board from doing anything about it.

By the early 1930s entrance depths were at record levels – about 6.4m – but the diversion of three Home boats in 1931 and the brief grounding of another two years later forced the Harbour Board to revisit its earlier plans. Ships were still getting bigger. In 1933 the board commissioned engineer F.W. Furkert to report on options. He recommended a 280-m extension as the first stage, taking the channel out to the 6.7m mark; later extensions could go out to deeper water.

Keen to use unemployed labour and to further economise by using rock from its own quarry, the board raised the height of the breakwater along the landward end in 1936 to form a relatively dry base for new work, and began dumping rock for the Ramsay Extension, as it was called, that year. G.A. Lee from Auckland was the supervising engineer.

The breakwater raising had been done with concrete. The Ramsay Extension was made from rock from the quarry near the foot of the breakwater. Although handy and cheap, the stone from this source was not very durable. The extension made only slow progress – barely 7m in 1939 – and was well short of Furkert's recommended length in 1944 when it was sealed off and abandoned.

By then its raison d'etre had gone. In 1941 the overseas shipping lines centralised calls on the main ports and the Home boats would never return to Oamaru. The Ramsay Extension was left to crumble, as it would, given the soft nature of the quarry rock. Today only a few fragments remain.

The loss of the Home boats was a deeply resented psychological blow and the Harbour Board would lobby for their return for nearly 20 years. But when it came to the port's trade, the quantity of cargo going over the wharf actually increased. From annual averages in the high 30s, cargo tipped 51,000 tonnes in the late 1950s, all from coastal and trans-Tasman ships. More cargo, less dredging, all seemed well for the port. Sumpter Wharf was used only once after the war. Holmes Wharf, which could handle two trans-Tasman ships or three small coasters, was perfectly adequate. Normanby Wharf had been given over to the fishing industry during the war and the Macandrew and Cross wharves had not seen a ship for decades.

But, although the shipping companies had rebuilt their fleets after the Second World War, the conventional (break bulk) cargo ship had reached the end of its development potential. Port congestion and escalating onshore costs were making the coastal business unprofitable as the state-owned New Zealand Railways (NZR) sought increased market share. The advent of the new Cook Strait rail/road roll-on, roll-off (RO-RO) ferries from 1962 onwards enabled NZR to eliminate the delays and the costly double handling that had previously made it uneconomic to rail goods across Cook Strait. When NZR formed alliances with private sector freight forwarders (who leased large amounts of rail space and sub-leased it to customers), the speed and flexibility offered by the train/truck combination proved too attractive to shippers. The general cargo trade to North Island ports began to wither. Some coasters were converted to bulk carriers for the grain trade, which was still able to remain competitive.

The final development work came in the late 1960s/early 1970s as the mole was widened to enable articulated grain trucks to work the wharf more efficiently and Holmes Wharf was redecked. By now the Cook Strait road/rail ferries had all but killed off conventional coastal shipping. In 1974 the last ship called and four years later the Oamaru Harbour Board was abolished, its duties taken over by a harbour committee with representatives from the borough and two neighbouring county councils. That year the port was formally closed to shipping.

The port slumbered throughout the last quarter of the twentieth century. New Zealand Cement Holdings, part of what is now the transnational cement manufacturer Holcim, had plans for a cement works at Weston, just outside Oamaru. In the late 1970s the company prepared plans for a bulk loading facility on Holmes Wharf, the demolition of Sumpter Wharf to increase the swinging basin, and for dredging the harbour down to enable 8,000-tonne capacity bulk carriers to use the port. Cement Holdings won a ministerial appeal to reopen the port against the opposition of the New Zealand Ports Authority, the Timaru Harbour Board and NZR, but the recession of the 1980s put the plans on hold. Holcim (NZ) Ltd is currently investigating the Weston options, but given the state of the port and the desire to export cement as well as supply the domestic trade, it now plans to rail cement to Timaru for shipment.

Figure 8: Oamaru Harbour in 2008, looking at an early 1900s railway pedestrian bridge and Holmes Wharf. – Gavin McLean

In the absence of any revenue-producing cargo, the port deteriorated gradually. Normally dredged every three years or so, the entrance shallowed badly and by the 1990s even small inshore fishing boats were having trouble entering port safely. The Oamaru Harbour Committee, from 1989 a committee of the Waitaki District Council, had little money, no long term strategy and was preoccupied by the state of the breakwater, which was damaged again in the 1980s.

The turnaround came in the mid-1990s, when the committee finally gave up on hoping for eventual rescue by the cement company and developed an asset management plan. Maintenance of the breakwater was now seen as essential to protecting part of the central business district from coastal erosion so the council decided to repair the structure. It also set a policy of maintaining the harbour entrance depth at 4-m at low water. The first dredging since 1971 took place in 1997, enabling naval patrol boats to resume port calls.

Although the nearby Harbour/Tyne Street historic precinct had been under restoration since the late 1880s, and Oamaru had rebranded itself as a 'Victorian Town at Work', little attention was paid to the heritage values of the harbour itself. The short span of the almost disused railway marshalling yards acted as a physical, but more seriously as a psychological barrier. In 2003, for example, the heritage values of part of Macandrew Wharf were damaged in a botched repair job to the breakwater – this despite the fact that the entire structure was registered Category II by the New Zealand Historic Places Trust. Shortly afterwards the port area was registered by the Trust as an historic area.

Figure 9: Holmes Wharf (left) and the breakwater, viewed from Cape Wanbrow in 2008. The large rocks on the seaward side are the remains of the Ramsay Extension. – Gavin McLean

In 2007 the North Otago Branch of the Historic Places trust commissioned marine engineer Nick Barber to prepare a conservation plan for Sumpter Wharf, now seen as of considerable heritage significance for its links with the first years of the frozen meat export trade. Conservation was estimated to cost about $1 million. An interpretation programme is being planned to guide visitors from the Harbour/Tyne Street precinct down to the waterfront and out to the penguin colony near the foot of the breakwater.

Figure 10: Shagged? Sumpter Wharf, fenced off, is a haven for seabirds while fundraising gets underway for its conservation. – Gavin McLean

The Council has dredged the entrance twice since 1997 and has completed further repairs to the breakwater and has placed further tetrapods to armour its vulnerable seaward side. The Macandrew and Cross Wharves had not been used for decades, but Normanby Wharf (which Sanford leases) and Holmes Wharf are maintained for 'commercial' (i.e., fishing industry) use. Sumpter is fenced off in the meantime.

Oamaru Harbour remains the country's best example of a Victorian/Edwardian export port. Bigger, more successful ports reconfigured themselves to gear up for the container age. Port Chalmers, for example, filled in its two graving docks and buried the old wooden finger piers beneath a massive reclamation for container handling and stacking. So did other ports as the size of ships took off and the demand for cargo storage climbed. Oamaru did not and still gives the appearance and scope of a colonial export port.

CONCLUSION

The Port of Oamaru has been closed to commercial shipping for nearly four decades. For almost two decades of its almost 120-year-long trading life it was under the thumb of the receiver. Given that chequered past, was it worth the expenditure and the duplication that Belich mentioned earlier?

The simple answer is yes. Before the era of trains and more particularly, modern heavy trucks, towns depended on shipping to survive, let alone grow. In 1879, the main South Island settlements – Dunedin (40,880 inhabitants), Christchurch (22,946), Nelson (6,804), Invercargill (6,683), Oamaru (5,098) and Timaru (3,791) were all seaports – the largest inland settlement, Ashburton, had just 1,200 inhabitants.[13] A functioning harbour was essential to securing provincial or sub-provincial heavyweight status. Interestingly, a New Zealander in 1879, looking at Oamaru's larger population and its more successful harbour works, might have found it hard to imagine that in 2009 Timaru was handling international shipping and that its population was more than twice that of its southern rival.

Similarly, in 2009, settlements that vied with Oamaru to become the capital of the North Otago sub-region, but which failed to develop deep-water ports, Kakanui and Moeraki, are mere hamlets of a few hundred people. With nearly 13,000 inhabitants, Oamaru is still Otago's second-largest settlements. In a sense it is still living off that late Victorian investment.

The Port of Oamaru's eventual failure can be attributed to a number of factors: the small size of its hinterland, which was developed early and offered little potential for growth in the twentieth century; the absence of a low-value bulk cargo such as coal or cement to sustain it as such cargoes have done for Westport and to a lesser extent, Greymouth; the port layout, which struggled to keep pace with ship growth during the early twentieth century; and mid-twentieth century improvements to surface transport, which enabled trains and trucks to compete with conventional coastal shipping for all but the bulkiest cargoes.

ACKNOWLEDGMENTS

I thank the North Otago Museum for permission to reproduce photographs used in this article.

[1] The main secondary sources on Oamaru Harbour are: McLean, Gavin, 2008, *Kiwitown's Port: The Oamaru Harbour Story*, Otago University Press, Dunedin; McLean, Gavin, *Oamaru Harbour: Port in a Storm*, 1982, Dunmore Press, Palmerston North, and McLean, Gavin, 'Tide of History' in Kynan Gentry and Gavin McLean (eds), 2006, *Heartlands: New Zealand Historians Write About Where History Happened*, Penguin, Auckland.

[2] Thomson, William, 1866, Harbour Report, *Otago Votes and Proceedings*, 1866-9, p. 32.

[3] For a history of Otago shipwrecks, see Collins, Bruce, 1995, Rocks, *Reefs and Sandbars: A History of Otago Shipwrecks*, Otago Heritage Books, Dunedin.

[4] McLean, *Kiwitown's Port*, pp. 37-8.

[5] Ship tonnages are expressed as gross registered tonnage (grt), which is never converted into metrics.

[6] A report in the *Wellington Independent* on 4 March 1874 said that the blocks of concrete weighed 20-30 tons, and that some to be made in situ would be 80-120 tons each. 'The concrete is in blocks 12 ft long. One row will be laid on the outside of the formation, and between it and the inner row, the space will be filled up with rubble rockwork; on the top another layer of concrete blocks being made. The total width of the structure will be 36ft, and at the top it will be 12 ft wide. The surface of the upper layer will be only 5ft 8in above water-level.'

[7] The fullest account of the crane appeared in the *Otago Witness*, 26 July 1873. In August the same plant tested a 7-ton capacity crane for the same project.

[8] *Mount Ida Chronicle*, 19 Aug 1873. Final cost of the crane, including delivery, was £2,000.

[9] Email to author forwarded by Dr Danea Cowell, Sydney, 23 December 2008.

[10] *North Otago Times*, 9 December 1882.

[11] *Timaru Herald*, quoted in the *Oamaru Mail*, 6 September 1884.

[12] Belich, James, 1996, *Making Peoples: A History of the New Zealanders from Polynesian Settlement to the End of the Nineteenth Century*, Allen Lane, Auckland, p. 372.

[13] 1879, *Statistics of New Zealand*, Government Printer, Wellington, p. 244.

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Heritage and the Modern Railway

Euan McQueen.

SUMMARY: *Railways have a long and rich history, beginning in the 17th century in an industrial role, and meeting public needs from the early 19th century. In New Zealand, a nation of relatively recent European settlement, a national railway network (of varying scale and length) has been operating since 1863.*

The role of railways in New Zealand's economic development is significant in providing reasonable access to and from the hinterlands of our many ports, and helping to open up large areas of land to timber extraction, farming, and mining, with the associated growth of towns and villages. Over time various isolated sections were linked to form a national network which reached its greatest extent in 1953.

With the help of statutory protection from longer haul competition that role remained generally stable until the 1960s, when improvements in roads and road transport introduced more serious competition, and competitive restrictions were relaxed. Over the next five decades the rate of change in the role of railways increased steadily, including in the 1980s when protection from competition was finally removed. Major governance and operating changes were introduced at that time, and the network moved rapidly to a generally arterial rather than a traditional more local role in the country's transport.

One of the results of such major change has been the functional abandonment over a relatively short period of buildings and structures, and some types of locomotives and rolling stock. Some of these structures and stock had high heritage value, and one of the themes of this paper is to describe the community and institutional responses to the rapid creation of such a heritage inventory. The role of volunteers has been crucial, both at the national and local level. The goodwill from most of the various railway authorities over this period has been critically important, as has the availability of funding from many sources for a wide range of community based groups. The result has been the retention of much valuable railway heritage within the framework of an operating railway.

1. INTRODUCTION

This paper is not so much to celebrate New Zealand's railway heritage – and there is much to do in that regard – as to describe and comment on the ways that this rich heritage has been preserved and maintained; in effect, how that heritage has been managed.

Our railway heritage is a story of local industrial design, and adaptation from railways overseas; of local responses to New Zealand's challenging topography and widely dispersed settlement patterns, and of the response to limited budgets in a nation of small population and constrained funding for infrastructure expenditure.

Today, after nearly 150 years of railway operation, there is the continuing challenge of intense competition from road and air transport (for both passengers and freight), of serious questions from both government and vested interests about future funding and indeed the need for a railway network on its current scale, and the problems stemming from a range of significant legacy issues.

But first, an outline of the changing railway system over the last 50 years.

2. THE CHANGING RAILWAYS OF THE LAST FIFTY YEARS

For several decades until the 1960s, New Zealand's national railway network was in a relatively steady state. A few branch lines had closed in the early 1930s, a few more in the 1950s, and railways to Kinleith (1950) and Murupara (1957) were opened. In 1953 the maximum route length was reached - 5689 kilometres - but then began a steady and inexorable decline over subsequent decades as branch lines closed. From 1945 to 1955 total route length reduced by only 11 kilometres; from 1955 to 1965 the net reduction was 378 kilometres. That trend was to continue, until in 2009 there are 4000 route kilometres of railway on the national network, a reduction of 1689 kilometres since 1953.

The scope and nature of the railway system's operation to the 1960s saw increasing change. Remaining passenger services were being withdrawn from some branch lines, a few stations were closed, but most effort was assigned to moving growing freight tonnage in the post-World War II years as increased prosperity created new transport demands. It was a period of major land development projects. Increasing quantities of fertiliser and lime were required for these projects, and transport needed for the eventual livestock and wool. The growth in demand for industrial and consumer goods kept steady pressure on a network that was still struggling to get over the heavy demands of the lack of investment in first the Depression then the war years. Labour and materials had been scarce in that period; significant recovery of asset quality on the railway was not to come until the 1970s.

The railway system in the 1950s was still orientated to meeting local and rural needs as much as toward longer haul inter-regional haulage. Since 1936 competition from road transport for freight alongside open railways had been limited by law to 30 miles (48 kilometres) for all but a few commodities, or for freight moved with a special permit.

With this degree of protection from road competition, the Railways Department was obliged to serve the many small communities and farming areas along its network. In 1952 there were over 1000 stations handling general freight on the network, plus many private sidings serving a single user. There were, in addition, over 150 small stations without freight sidings, handling passengers, parcels and small lots - consignments that could be handled by one man from the train to the station . In many areas these small flag stations were well used into the 1960s for parcels and smaller consignments: mail, groceries, newspapers, boxes of fruit and sacks of seed were all frequently seen, especially on routes where roads were poor.

Today (2009), there are 17 freight centres where all types of freight are handled, plus a few score private sidings for individual users and another small group of stations which see use for bulk freight traffic such as logs. The only small stations remaining without freight sidings are those used by commuters in the Wellington and Auckland regions, and a few on long-distance passenger routes.

In 1952 there were 74 stations between Christchurch and Dunedin with sidings handling general freight, plus numerous private sidings. In 2009 there are four such stations (Ashburton, Temuka, Timaru and Oamaru) plus a few major private sidings serving particular industries away from these four stations. A few other stations still have sidings and will handle bulk consignments in multiple wagon-loads as required. And the nine rural branch lines that left the Main South Line between Christchurch and Dunedin in 1953 had all closed by 2002, taking with them some 75 stations. Trucks, both those linked to the railway operation and those operating independently, now provide the freight transport needs for those areas.

3. THE REASONS FOR CHANGE

The factors that brought about such change in railway operations in the second half of the 20th century are many and varied. Key elements included:

- Major advances in the capabilities of commercial road freight, with bigger and more efficient equipment becoming available. This trend applied particularly from the 1970s onward.

- The progressive reduction of competitive restrictions between road and rail in stages from 1961 to their complete abolition in the mid-1980s.

- There were significant changes in freight-handling practices on farms and in factories, timber mills and other industries. For example, from the mid-1960s on, most grain was increasingly handled in bulk, rather than in sacks. Farm storage incentives became available to reduce the intensive peak of activity at the annual harvest, which then relied largely on the railway and local stations to get grain to flour mills as it was harvested. Potatoes were increasingly handled in bins, rather than sacks. Forklifts and pallets became the norm for most freight handling. These and other efficiencies led to the centralisation of handling, production and processing in many industries, such as seed processing, flour milling, timber production and coal handling. The demand on local railway facilities to meet the needs of farmers and smaller towns diminished; and often railway wagons and older rail-served factories did not match the needs of the new handling techniques.

- Some traffic virtually disappeared. Coal carried by rail to dairy factories and other plants in the North Island was replaced largely by natural gas supplied via pipelines in the 1960s and 70s. Coal gas plants all over New Zealand disappeared from the 1960s to the 1980s, and with it a significant tonnage of coal carried by rail. Coal-fired steam locomotives disappeared from the network in 1971 after a progressive change to diesel power over the previous two decades. Domestic coal demand diminished sharply as the use of coal ranges reduced and open fires were replaced by more efficient wood burners fed by local firewood, rather than coal from a distant mine.

- The rationalisation of the dairy industry saw, from the 1960s, a progressive reduction in the number of diary factories. Where once there were seven factories along the 37km Opunake branch in Taranaki, by the 1970s there was only one specialist plant at Kapuni. Dairy processing in the southern half of the North Island was increasingly concentrated at three plants at Whareroa (south of Hawera), Longburn (near Palmerston North) and Pahiatua. Whareroa today draws milk from all over this area (much of it by rail). This is traffic on an industrial scale; it is no longer local, where the farmer can see his production go out of the local station and the coal come in to 'his' dairy factory via the same station.

- Ports, from the 1970s on, experienced major change in their demands on railways. The 'railway port', including most of the South Island ports, had begun to change cargo-handling practices by the early 1960s so that there was very little of the short haul and costly traffic between the ship's side and local stores or goods sheds. It was not unusual in 1959 to have over 1000 wagons stored under load around Christchurch after a 12 kilometre haul from ships unloaded at Lyttelton. It was inefficient, costly and not what a modern railway was really about. Change had to happen. From the 1970s traffic to and from ports was increasingly in containers handled in a terminal behind the port, or by truck. Wagons at ship's side are now a very rare sight - and the many small private sidings and small stations in both urban and rural areas to handle this short haul traffic became redundant.

- In rural areas (not only on branch lines) there was a further significant change: the release of any restrictions on livestock cartage in 1961, which saw the railway's very significant role in that traffic disappear in the 1970s apart from a few trial loadings in 1994.

- The free or cheap railage of lime, which produced many thousands of tonnes of traffic each year for Railways in the 1950s, much of it to smaller stations, was first reduced in scale then abolished. There was no longer the incentive to keep a station close to the farm for this traffic.

All these changes were matched by a decline in rural towns' commercial activity and an associated population reduction, as the cities and regional centres grew bigger and took over smaller town functions. Improved roads and road transport were important elements in this change.

In summary, the need for local stations and local lines (branch lines) diminished and disappeared. It was not a decline in farm output but a change in handling and transport methods. It happened with fertiliser: as bulk depots at central points served large areas, the demand for bagged fertiliser in individual consignments diminished. The then Railways Department moved quickly to close smaller stations and, in time, to remove their track and buildings. With that process came a significant visual change in the rural transport scene.

Thus, the local role of railway progressively disappeared. The process began seriously in the 1960s and moved quickly through the 1970s and '80s. The closure of rural branch lines was but part of that process. In the 1990s larger centres like Levin, Feilding, Pukekohe, Taumarunui, Balclutha, Gore and Westport lost their general freight role, leaving only a few private sidings or bulk traffic handled by rail. Stations within the main urban areas also lost their freight function, though not the passenger traffic in Auckland and Wellington regions. Papakura, Lower Hutt, Rangiora, Burnside, all formerly busy stations, had their long-haul traffic brought into or taken from central urban freight centres by road. The use of container transfer between rail and road is relatively simply, and wagon utilisation improved sharply with fewer stations. But the offset was the loss of direct rail access for some industries, some of which simply switched to long-haul road transport, or coastal shipping plus trucks for inter-island traffic.

There have been many judgements and generalisations made about this trend. Few have rested on a knowledge of costs, prices and the hard information held only by customers, road transport operators or the railway operator.

Today, in 2009, it is a very different railway from the 1950s. There have been huge operational changes within that 50-year span - from steam to diesel, in signalling, in mechanised freight handling, in train operation and reduction in shunting, in the scale and nature of passenger traffic, in the nature of competition and the perceived efficiencies of road transport, and in the qualities of management brought to all forms of transport. It is a tough, competitive, customer-driven industry - a far cry from the more informal, intimate, regulated yet rather more relaxed style of 50 years ago.

Those days are gone. If one yearns for their resurrection, it is but an exercise in nostalgia. They reflected a different pace of life, different transport technologies, an intimacy between rural areas and their railway, which was still the only truly national transport organisation and operator until probably the 1980s. It has been an inexorable change, not without a price to customers, communities, road users other than for freight and those in the transport industry. But it had to happen. Today, the railway system carries more tonnes in a year than for any year before in its history. But these are different tonnes from earlier times, to and from different places and often in different and certainly much bigger wagons and trains. There is a huge increase in productivity.

For a comparison ‘in the flesh’ of the scale of these changes, one must visit railway heritage sites and compare the seemingly tiny wagons to the present fleet of 50-plus tonne capacity. Without changes such as those, there would now be only the remnants of the original railway system - or perhaps none at all.

4. ATTITUDES TOWARD HERITAGE

Like most nations of relatively recent European settlement, New Zealand’s settlers of the 19th and 20th centuries were so busy in their first century of settlement that preserving heritage was not a high priority. The traditional museums were in time established, like the former Dominion Museum in Wellington, and contained lots of scientific displays, Maori artefacts and other items usually set out in a less than exciting manner. Local and district museums were often the result of the work of a few residents, who realised that their local history was disappearing and set out to collect it. But the overriding priority was still settling into a new country, and then being distracted by two world wars and a major depression. The recovery period from World War II left most people so busy (remember, those were the years of virtually nil unemployment), and with huge demands on public funds for replacing worn out public assets such as hospitals, roads, railways and schools, heritage just did not rate highly. Anyway, who wanted to recall a past which was dominated by two world wars and a major depression?

This began to change in the 1970s, as people sought to confirm their role as New Zealanders, not transplanted Scots, English or Swiss. There was a growing sense of our own history, both Maori and European, and of the need to recognise and record things which were changing very quickly. This was the case with railways, perhaps sharpened by the change from steam to diesel which began in the 1950s. Suddenly traditional technology was being challenged, and those with vision saw the need to hold, and perhaps restore, examples of what was going to disappear from the working railway scene. Already photographers and archivists had detected the trend, and were busy in their very valuable role.

The heritage and preservation aspects of technology - including transport - did not rank highly until relatively recently. NZ Historic Places Trust initially concentrated heavily on archaeology, and buildings and architectural history; technology was recognised with the Hayes wire strainer plant in Oturehua and a few other sites, but not much else. Industrial archaeology, as a discipline, saw little general recognition until the 1970s.

5. RECOGNITION OF RAILWAYS HERITAGE

Before the mid 1940s there were no formal heritage or rail history groups in existence in New Zealand. There were certainly individuals, with in some cases extensive collections of photographs and documents. Some of these people exchanged information and sources.

If one was interested in overseas railways before World War II, the literature came from Britain (e.g. the Meccano Magazine) or United States (such as The Railroad Magazine). In 1944 the New Zealand Railway and Locomotive Society was established in Lower Hutt. Tom McGavin, the founder, along with a number of supporters, had a deep knowledge and interest in New Zealand’s railways.

Tom McGavin’s major interest was to record, in both files and by publication, the history and significant events in New Zealand’s railway history, including light railways and tramways. He produced and edited the Journal of the Society, the NZ Railway Observer, for an astonishing 54 years, and maintained a lower- key role for some years after that.

The Observer brought together many people from around the country who at that stage were not aware of the scale and interest amongst others. Branches of the Society were established, and over the following decades, excursions run, branch newsletters sent out, and meetings held. Other groups were formed. The heritage of New Zealand Railways (NZR) was at that stage essentially recorded by camera, text, and 35mm film rather than by artefact. The railway network, in the 1940s and 1950s, seemed so permanent, as did many of the locomotives and structures. Why preserve it when it was still working?

But the process of serious change began in the 1950s, after the findings of the 1952 Royal Commission into the future of New Zealand's Railways, and the advent in the early 1950s of the first main line diesel locomotives. Diesel shunting locos were already on the scene.

The Observer recorded the closure of branch lines, the advent of the new diesels, and the progressive disappearance or reduction of well established parts of the railway scene – the provincial passenger expresses, local and suburban passenger trains outside the main centres, and some of the many small private railways and tramways serving sawmills, coal mines, and other industrial sites.

6. THE DEVELOPMENT OF RAILWAY HERITAGE GROUPS

It was in Dunedin, in 1963, that the Ocean Beach Railway was established at St Kilda, with the general aim of rescuing and restoring smaller locomotives and rolling stock from both Railways and local industrial sites - some of the locos very old, and including examples of early NZR stock. Other groups followed in different parts of the country, with an increasing pace of saving locomotives (in particular), but also rolling stock. The rapid advance of main line dieselisation throughout the 1960s, with steam on the main line finishing in 1969 (North Island) and 1971 (South Island) prompted immense effort from individuals and small groups to obtain examples of locomotives before they were scrapped.

It was in this era - the late 1960s and the 1970s - that the major locomotive restoration projects were founded. While there was some rolling stock preservation, the wagons of the mid-twentieth century had not begun to disappear with the same speed as steam locomotives.

Carriage stock was increasingly disappearing from NZR holdings as the named passenger trains, with assigned stock, came into service. Wooden sheathed stock was no longer used from the 1970s, other than on private excursion or tourist services.

The main line passenger carriage fleet was rapidly diminishing; most sleeping cars were scrapped shortly after the Silver Star came into service in 1971; the original Northerner service kept four (refurbished) sleeping cars operating: two of these are now preserved.

From the mid-1970s onward stations and other infrastructure were beginning to become redundant on a large scale. Many rural branch lines had gone by then. The first signs of community interest in preserving stations were appearing. Community interest groups saw their local station threatened, and moved to save it. Carterton, Helensville and Ohakune are good examples. Loco watering tanks, already rare, became prized possessions; and railway groups with a mixed community/railway interest were established not only to save but also restore significant stations - Ormondville being a classic example. NZ Railways Corporation was sympathetic to these projects, developing the concept of heritage lease agreements which helped protect buildings and other assets.

The Rail Heritage Trust of New Zealand (RHTNZ) was established in 1991, to help record, protect and preserve significant elements of our railway heritage. With much help from others already in the field, the Trust's work began slowly, but increased rapidly, as the great four-wheeled wagon clearout began in the mid-1990s.The Trust's role evolved as providing links between heritage groups. the railway authority(s), and local government. This latter liaison has proved in some cases to be pivotal in the success of a project.

The Trust is an informal adviser to KiwiRail on heritage issues. Amongst other work, the Trust got NZ Rail Ltd's agreement to the concept of heritage leases for wagons, and some 120 wagons and carriages were transferred to groups around the country, usually with minimal cost to the recipients. The methods by which these wagons were chosen, allocated, and transported are best lost in the mists of history; all I can record is the quiet but very real support from many Railway staff for helping implement this project, which has contributed hugely to the fleet of heritage rolling stock in New Zealand.

In essence, RHTNZ was the result of an implicit outsourcing of the management of railway heritage. The work generated for the Trust was at times overwhelming, and continues to grow. It is operated on a semi-voluntary basis.

And I must pay tribute to the Federation of Rail Organisations of New Zealand (FRONZ), established in the 1970s, which acts as both a focal point especially for heritage operating groups, as well as a more general advisory role with all member groups in terms of information, lobbying and advocacy. Paul Dillicar, the current President, has spent some 35 years, along with his Board colleagues, as volunteers in this cause.

7. DEPENDENCE ON VOLUNTEERS

The human basis for these developments was, with very few exceptions, volunteers. As groups grew in scale and range of activities and became more ambitious, funding was obtained from the trusts and charities which support good causes throughout the community. One could argue that the value of the resources within the groups' collections is such that the community should be looking to support the rail heritage sector in a more structured way, but without destroying the interest which those in the groups must continue to enjoy as volunteers.

Let's look more broadly. The two major and funded institutions with potential for involvement in railway heritage are the NZ Historic Places Trust (NZHPT) and the Department of Conservation (DoC).

NZHPT has a very broad brief on heritage matters, but it does not have the ability to become involved in potentially mobile exhibits. A most important role is its ability to register significant places. I believe that their current involvement in railway heritage is reasonable, in the context of the huge demands made on their limited resources for the entire heritage sector. There has certainly been a marked increase in railway station and site registrations in recent times, much of it prompted by the North Island Main Trunk (NIMT) railway centenary in 2008 and RHTNZ.

The Department of Conservation (DoC) has come to the railways and industrial heritage scene relatively recently, as 'owners' of former railway and industrial sites within its estate. I am impressed with what is being achieved. The minor railways - bush trams, mining lines, and often associated sites, have been difficult to preserve in many cases, usually because of remoteness. Industrial archaeology, as a discipline and in practice, has not had much of a profile in our national heritage policies until relatively recently. DoC has begun to fill that gap, and I think it is doing it very well. Two people, Paul Mahoney and Jim Staton, (both from DoC), have taken a leading role in this work.

The contrast between the rail heritage sector in general, and NZHPT and DoC, is stark on two counts; the availability of funds and permanent employed staff, and the relatively less significant role of volunteers in the HPT and DoC situation.

8. CASE STUDIES

Let's consider three case studies, with involvement from both parties to varying degree, plus others.

1. The reconstruction of the Brunner Suspension Bridge, re-opened in March 2004. This project cost some $678,000, and apart from volunteer time in its administration, was planned and executed by professional bodies on a commercial basis. No local volunteer group could take on a project of this complexity and cost. It is a significant item of New Zealand's engineering heritage, linked to a major industrial heritage site.

2. The Charming Creek Walkway. A much older and smaller project, but just as significant in industrial archaeological terms. While the redevelopment of the former coal tram right of way was nothing like the scale of the Brunner Bridge, the need for interpretation, restoration and above all maintenance for safety and accessibility is critical. In this case, DoC has the funding, the infrastructure, and the skills to keep this deeply interesting and attractive site open, and to allow access to scenery and recreation as much as to industrial archaeology.

3. The restoration of Top Brake of the Denniston Incline, a challenging task carried out by a mix of contractors and DoC staff brought in from the West Coast as "volunteers".

9. RURAL STATIONS

In the volunteer sector, some of the best local or community-based heritage has been applied to the restoration of rural railway stations - Ormondville, Waverley, Shannon (with its Manawatu Railway Company station), Ohakune and Moana are examples. Most have parts of the traditional freight handling facilities still standing and either restored or with restoration under way.

10. LARGER STATIONS

Dunedin, one of New Zealand's most notable buildings, has been restored by Dunedin City Council, with major help from the Lottery Grants Board. The Taieri Gorge Railway headquarters is in the station; the remainder of the building is leased for other purposes.

Wellington Station has just had a major refurbishment (including seismic strengthening) completed, funded by the Crown. The traditional railway administrative presence occupies half the building, the other half is leased to Victoria University of Wellington.

Blenheim, a significant Troup station, was restored in the 1990s, and is used as the town's Information Centre as well as a railway station. (George Troup was employed by the Railways Department in the early years of the 20th century, and designed many outstanding railway stations in his time, including Dunedin).

Mataura (another Troup station) is sustained by rent from a café and is used by railway operations staff. And there are many other examples around New Zealand.

On the other hand, there are buildings threatened with demolition such as Ashburton and Whangarei; no practical use can be found for them on their current sites.

11. BRIDGES

New Zealand's topography calls for ingenuity in design and construction of railway infrastructure. There are significant bridges on most routes; perhaps the most notable collections are on the North Island Main Trunk, and the Midland Line between Canterbury and the West Coast. The former Otago Central Railway, both on the extant section to Middlemarch, and on the Rail Trail, has a diverse collection of bridges, including many using local stone for abutments, right down to small culverts.

Many of these (and other) bridges have been strengthened, sometimes more than once, in their long lives. Others of note have had to be replaced recently: the timber truss structures at Cobden, near Greymouth, and Arahura (combined road and rail) between Greymouth and Hokitika are significant examples.

Routine and essential renewals will inevitably take their toll on remaining heritage structures, but in some cases ingenuity is applied as was the case at Paroa, near Greymouth, where steel supports were inserted and faced with traditional beams. In the case of the two large truss bridges noted above, spans have been kept and will be placed nearby, along with photographs and information to mark their heritage significance. A detailed photographic and design archive was created by the railway authority before the bridges were demolished.

12. LOCOMOTIVES

The New Zealand locomotive fleet has always been a mix of local and overseas design and construction, with the balance varying over time for a variety of reasons.

There is a proud history of local steam locomotive design and construction, with the first steam locomotive built in a NZ Railways workshop dating from 1889 (Addington). The locomotive still exists, in working order, at Canterbury Railway Society's site at Ferrymead. It is owned by the Rail Heritage Trust of New Zealand.

Major classes of locomotive were designed and built in New Zealand. The K class (K, Ka, Kb) were in this group. Many of the Ab class, the workhorse of the fleet for many years, were built in NZR workshops, others at A & G Price at Thames, and in Scotland. The J class were built both in New Zealand and Scotland. Earlier locomotives were built in Britain, and some in the USA.

Not all classes have been preserved, but a good sample has been kept, a few at main line running standards, a larger number for operations on heritage sites or routes.

Mainline diesel locomotives have all been built in the UK, USA, Australia, Japan or Canada, although smaller diesel locos (shunters and industrial locomotives) have been built locally, both in NZR workshops and privately.

Most of the locomotive restoration work has been achieved entirely by volunteers. A significant exception is the collection developed by MainLine Steam, funded by Ian Welch. He has added notably to the range of restored steam locomotives, many of which operate on the national network.

13. ROLLING STOCK: PASSENGER

Except for some early carriages, New Zealand developed its own designs for passenger carriages and guards' vans, and built them in New Zealand Railways workshops. Exceptions have been the last orders of guards' vans, the Silver Star express, most railcars, and suburban electric stock.

Modern suburban stock is either built overseas, or new designs developed and then rebuilt from pre-used imported carriage bodies.

14. FREIGHT STOCK

This has been a mix of New Zealand and imported stock over the years. The lumpy pattern of investment funds over the later 20th century often led to large orders being placed overseas simply to get stock supplied quickly, while NZR workshops concentrated on overhauls and shorter runs.

Good selections of most of this range of rolling stock have been retained on heritage sites, and in many cases, faithfully restored. A limited number of carriages are certified for main line running, an activity which is carried out entirely by trained volunteers, all under clearly defined standards and practices set by the railway authority and the regulator.

15. FORMAL PROTECTION OF RAILWAY HERITAGE

Buildings and sites can be registered with the New Zealand Historic Places Trust, but not mobile equipment such as rolling stock and locomotives. The NZHPT has been listing railway stations, and other structures, for some time, with an increasing pace of registrations in recent years. As almost all railway buildings have been of timber construction, there is increasing pressure to see a good sample preserved. Stations listed in the Rail Heritage Trust register are listed in Attachment A, with NZHPT registrations noted. The RHTNZ Register has no statutory basis.

We have as well, in the context of railway heritage, an unusual registration - 200 route kilometres of the North Island Main Trunk railway.

The centenary of the NIMT in 2008 was a notable event, in terms of re-establishing links with the railway's communities, reminding Kiwis about the role of this railway, and celebrating a century of activity on what has been one of New Zealand's busiest railway routes.

The New Zealand Historic Places Trust has carried out a heritage research project in the Ruapehu District in the centre of the island (and the NIMT). The Trust proposed that a 200 kilometre section of the railway be registered as an historic site (between Makatote Viaduct and Taumarunui).

To register (and by inference, protect) a working railway is a novel move, and there was a natural concern within KiwiRail that there could be restrictions placed on repair, maintenance or reconstruction work while heritage issues were resolved.

Some years ago a detailed Memorandum of Understanding was signed between New Zealand Historic Places Trust and the then Transit New Zealand, the state highway planning and construction agency (now New Zealand Transport Agency). This document was used as a model for registration and protection of the 200 kilometres of railway, and with minor changes made, it should be signed soon. This, to me, sends a good signal about the links between heritage and the modern railway.

Local government is now registering a significant range of railway structures in their District Plans. This can provide statutory protection, which does not necessarily arise from either NZHPT or RHTNZ listing. RHTNZ is now taking a key role in prompting these registrations. If a site is pre-1900 it is protected under the Historic Places Act as an archaeological site.

16. REVIEW AND PROSPECT

First, some comments about transport and the public:

- All transport - including railways - is far more complex in its funding, operations and management than is generally accepted by the public.

- Transport - including railways - is a very public industry. It is ubiquitous. Mistakes, faults, (real or imagined), accidents and most of the sector’s activities are there for the media, enthusiasts and others to remark on, which they do with glee. An industry confined to one site can usually contain all but their major mishaps within the plant site. Transport, and railways, cannot do that.

- The state has, and always will have, a role in transport as either an operator, owner or regulator. Thus there is always a political element in significant decisions.

- The public/political matrix produces at times a level of public debate about transport which can both inform and mislead, and is at times profoundly ignorant. Railways, for long a butt of comedians and political influence, have had their fair share of this.

- Given all this complexity, and public exposure, there is a tendency for railway and transport managers to despair of ever getting a message across which can both cover the complexities of their industry, and at the same time, not get boring. Many give up. remain quiet, and misinformed comment thus becomes folklore.

- Thus the transport system, critical to a nation’s survival, battles on not only with all the normal challenges of operational survival, but also with a montage of perceptions, folklore and myth which settles like an aura around it.

These general points, which are by no means unique to New Zealand, provide a backdrop for both the current scene, and what has happened in the past.

I would suggest that the opportunities for misunderstanding which could occur between heritage issues and the modern railway are potentially legion. I believe the New Zealand solution, which I have outlined in this paper, has allowed both interests - the operating railway and heritage principles and practices - to co-exist, not without misunderstanding and tension especially in the earlier stages, but in most cases with a mutual desire to look for a solution.

This has been helped by our being a small country, with a small population. But I see a will and interest in the current railway authority to accept the existence of a significant rail heritage community, and to be reasonable and, at times, proactive, in contributing toward good relationships. The 2008 North Island Main Trunk centenary was a brilliant example in which Ontrack, the then infrastructure company, played a leading role in association with heritage railway operators (to their mutual benefit) and at the same time, met community desires.

17. SUMMARY

The growth of the rail heritage sector since 1945 can be summarised as follows:

1940s	Individuals, but no organised groups.
1945-1960s	Emphasis on recording rail history, and changes to the current scene.
1960s-1970s	Rapid movement toward establishment of groups to save/restore steam locomotives, and some passenger stock.
1970s-1980s	More heritage groups established, including the early community-based groups to preserve stations.
1980s-1990	Significant progress toward locomotive and rolling stock preservation, the establishment of private railways on abandoned branch lines or independent sites, and station preservation.

1990-2009 Continuing growth in the number of rail heritage groups throughout the country; heavy emphasis on acquiring soon to be extinct classes of wagons, and their restoration; increasing awareness of the need for heritage integrity in both building and rolling stock restoration; first moves toward seeking recognition of some sites as actual or incipient museum sites.

The establishment of a Christchurch based group to develop plans for a National Railway Museum based at Ferrymead.

Lying behind this picture of growth in both scale and quality lie four fundamentals:

- There is now a growing awareness of the economic benefits of heritage in the tourist and recreational sectors. Rail heritage fits well within that context.

- Rail heritage now plays a significant role in the recognition and recording of our social, architectural, engineering and economic history.

- Most of the sector’s development has been achieved by volunteers and private support, but with an increasing major contribution by DoC in recent years in the industrial archaeology and industrial railways.

- The charitable funding sources for the volunteer sector are, to a degree, unpredictable, but without them there would have been little progress. And there have been significant contributions from a few individuals.

This is a picture of steady growth, with surges of activity at particular stages to salvage heritage items before they disappear forever. This huge voluntary effort has produced a situation where railway heritage is now a significant sector in its own right within the national heritage scene.

18. PROSPECTS

For the modern railway, there are the challenges of survival in a highly competitive transport sector, and within a political context which shows a current preference for expenditure on roads rather than public transport and railways, a view well outside current thinking overseas. In the financial consequences of such a climate, expenditure and time commitment to heritage issues could easily become very marginal.

For the heritage groups, future risks include an ageing volunteer work team with only limited replacements available, and the loss of craft skills. There will often be a preponderance of older people in voluntary groups; they are the people with the time, largely free of children, mortgages and the need for full time work.

It is this group, in railway heritage circles, which holds much of the skill base for the maintenance and restoration of older equipment, especially steam locomotives, and the driving of this equipment. This risk is now recognised, with Shantytown Museum (near Greymouth) now providing an approved training course in steam engineering and operations. And FRONZ is also working hard toward solutions in this area.

But there are other challenges. Ageing equipment will in time lose its capability to run on the national network, and to comply with the high standards expected by both the rail operator and the regulator (and the public). Some of the older stock will become static exhibits, rather than able to operate; but not everyone wants to be in a museum environment where the rolling stock is static . But larger groups are responding with new and higher standards of rolling stock as the tourist demands continue to grow. The Taieri Gorge Railway is a good example

Today, I see heritage and the modern railway, in the New Zealand context, as in a healthy state. Heritage has no boundaries, and there will always be more to aim for, and to achieve. The strength of the volunteers who have done so much in their area over the last 50 years shows no sign of diminution. It is these groups who will keep this important part of our transport history to a good strength, along with the quiet but important support from professional groups such NZHPT, DoC, IPENZ, RHTNZ, FRONZ and the communities in which those groups work.

19. ACKNOWLEDGEMENTS

I am grateful for help from my colleague Mike Mellor, Executive Officer of RHTNZ, for preparing the information shown in the spreadsheet about the Rail Heritage Register, and for significant help in finding and preparing the images used in the presentation.

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RAIL HERITAGE TRUST OF NEW ZEALAND
Buildings listed in the Rail Heritage Register, October 2009

Name	RHTNZ Category	NZHPT Category	Region	Type	Built	Building Ownership	Current use	Notes*
Auckland Station	A	I	Auckland	Main city station	1930	Ngati Whatua	Student accommodation	r
Blenheim Station	A	II	Marlborough	Troup Vintage station	1906	KiwiRail	Information and travel centre	p,r
Christchurch Station	A	II	Canterbury	Main city station	1960	Christchurch Science Technology Trust Board	Science centre	
Dunedin Station	A	I	Otago	Main city station	1906	Dunedin CC	Tourist railway, museum, offices	p,r
Greymouth Station	A	I	West Coast	Vogel class 2 station	1897	KiwiRail	Travel centre, refurbished 1990s	p,r
Moana Goods Shed	A	Hist. Area	West Coast	Rural goods shed	c.1900	RHTNZ	Vacant, to be restored	
Moana Station	A	Hist. Area	West Coast	Troup class A station	1926	RHTNZ	Vacant	p,r
Ormondville Station	A	II	Manawatu-Wanganui	Modified Vogel class 5	c.1883	KiwiRail	Heritage railway	r
Pukerangi Station	A	-	Otago	Tablet station	1891	Dunedin CC	Tourist railway	p,r
Reefton Station	A	-	West Coast	Class 2/3 station	1892	Reefton Historic Trust Board	Vacant	r
Remuera Station and Signal Box	A	I	Auckland	Island platform suburban station	1907	ARTA	Small business	p,r
Ruru Station	A	I	West Coast	Vogel class 7 shelter shed	by 1920	KiwiRail	Vacant	
Solway Station	A	-	Wellington	Vogel class 6 shelter shed	1880	KiwiRail	Shelter	p,r
Te Kuiti Station	A	II	Waikato	Troup class B station	1908	KiwiRail	Offices	p,r
Waverley Station	A	I	Taranaki	Modified Vogel class 4 station	1881	KiwiRail	Museum, station precinct	r
Wellington Station	A	I	Wellington	Main city station	1937	KiwiRail	Railway offices, university, supermarket	p,r
Arthur's Pass Station	B	-	Canterbury	Post-war island platform station	1966	KiwiRail	Railway station	p
Ashburton Station and Footbridge	B	II	Canterbury	Troup Vintage station	1917	Ashburton Station Souvenirs Ltd	Vacant	
Carterton Station	B	-	Wellington	Vogel class 2 station	1879	KiwiRail	Museum	p,r
Cass Station	B	-	Canterbury	Shelter shed	?1911	KiwiRail	Passenger shelter	p,r
Gisborne Station	B	II	Gisborne	Troup Vintage station	1902	Office of Treaty Settlements	Heritage railway	p
Glenhope Station	B	II	Tasman	Troup class B station	1912	Private	Hay shed	
Hundalee Station (relocated to Waikari)	B	-	Canterbury	Troup class A station	1939	Weka Pass Railway Society	Heritage railway	p,r
Inangahua Station	B	-	West Coast	Class 5 station	1914	KiwiRail	Vacant	
Inglewood Station	B	I	Taranaki	Modified Vogel class 4 station	1876	Office of Treaty Settlements	Vacant	
Invercargill Station	B	-	Southland	Post-war station	1978	YWCA	Offices	
Kaiapoi Station (relocated locally)	B	II	Canterbury	Troup Vintage station	1904	Kaiapoi Railway Station Trust	i-Site information centre	m,r

Kaikoura Station	B	-	Canterbury	Troup class B/C station	1944	Ngai Tahu	Tourist centre	m,p,r
Kawakawa Station	B	-	Northland	Troup class B station	1911	KiwiRail	Heritage railway	r
Little River Station	B	II	Canterbury	Vogel class 2 station	1886	Christchurch CC	Tourist and shopping centre	r
Lower Hutt Station (now Western Hutt)	B	I	Wellington	Troup Vintage station	1905	Station in Life Ltd	Pub	p,r
Matamau Station	B	-	Manawatu-Wanganui	Class 7 tablet station	1884	KiwiRail	Vacant	
Mataura Station	B	II	Southland	Troup Vintage station	1921	KiwiRail	Café, railway operations	r
Middlemarch Station	B	-	Otago	Vogel class 2/3 station	1891	Dunedin CC	Strath Taieri Lions Club	p,r
Oamaru Station	B	II	Otago	Troup Vintage station	1900	Whitestone Civic Trust	Offices	r
Onehunga Station (relocated locally)	B	-	Auckland	Vogel class 3 station	1873	Railway Enthusiasts Society	Society clubrooms	r
Otaki Station	B	II	Wellington	Troup Vintage or B/C station	1911	Office of Treaty Settlements	Office	p,r
Paekakariki Station	B	II	Wellington	Island platform station	1909	KiwiRail	Museum, café	p,r
Pahiatua Goods Shed	B	-	Manawatu-Wanganui	50 ft goods shed	1897	KiwiRail	Heritage railway	
Pahiatua Station	B	-	Manawatu-Wanganui	Post-war station	1971	KiwiRail	Heritage railway	
Picton Station	B	II	Marlborough	Troup Vintage station	1914	Picton Railway Village Ltd	Travel centre, restaurant	p,r
Plimmerton Station	B	-	Wellington	Island platform station	1940	KiwiRail	Vacant	p
Pukekohe Station	B	-	Auckland	Modified Troup class B/island platform station	1913	KiwiRail	Station	p
Rangiora Station	B	-	Canterbury	Troup class B/C station	1908	Private	Garden centre	p
Rotowaro Station (relocated to Pukemiro)	B	-	Waikato	Troup class A station	1918	Bush Tramway Club Inc.	Heritage railway	p
Seddon Station	B	-	Marlborough	Vogel class 4/5 station	1902	Private	Restaurant	p,r
Shannon Station	B	I	Manawatu-Wanganui	Modified Vogel class 4 station	1893	Horowhenua DC	Community centre	p,r
Springfield Station	B	-	Canterbury	Post-war station	1965	KiwiRail	Café, railway operations	p
Thames Station	B	II	Waikato	Troup Vintage station	1898	Ngati Maru ki Hauraki	Offices	r
Waihi Station (including railway houses)	B	II	Waikato	Troup class B station	1905	Goldfields Steam Train Soc	Heritage railway	p,r
Waitakere Station (relocated to MOTAT)	B	-	Auckland	Class 6 shelter shed	1879/1880	MOTAT	Museum exhibit	r
Wedderburn Station	B	-	Otago	Vogel class 5 station	1900	DoC	Rail trail shelter	r
Whangarei Station	B	II	Northland	Troup class C station	1925	Whangarei DC	Vacant	
Wingatui Signal Box	B	II	Otago	Signal box	1914	RHTNZ	Vacant - exhibit	r
Wingatui Station	B	II	Otago	Island platform station	1914	RHTNZ	Vacant	p,r

*** Notes:**

m - significantly modified

p - served by scheduled passenger trains

r - restored

The Prime Movers of Historical Change

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SUMMARY: *This paper is derived from the experience gained to date in producing the third volume of the "Biographical Dictionary of Civil Engineers in Great Britain and Ireland". The period dealt with in this volume is 1890 to 1920. For much of that time Britain had huge foreign investments supported by London-based consulting engineers. The Institution of Civil Engineers served as a learned society for many and an exclusive club for a minority of professional engineers throughout the British sphere of influence. The exclusive club promoted the concept of an empire-wide organisation able to use the services. The club organised "their" Institution to reflect this and sought alliances with overseas members for this outcome. Beyond the club but within the British Isles were more than half the membership of the Institution, who had little to do with the elites in Westminster, but shared some beliefs in a club of which they were part of an outer circle. To demonstrate the way the careers of such engineers developed a detailed case-study is given. It shows how one engineer, Thomas Aitken (1856-1918), fared.*

1. INTRODUCTION

"A Historian …. has to understand the minute variances that are the prime movers of historical change: the choices an individual can make, from the identical background as everyone around him, to crave something….entirely different from the "popular" choice." (1)

Emerson's dictum that "all history is biography" can be interpreted in various ways from the "great man approach to history" to ensuring that no individual is forgotten. The use of biography in the study of entrepreneurship has developed a pedigree in certain schools of business (2). It has been used to re-interpret events in varied industrial and commercial settings (3). There are some shared attributes of entrepreneurs and engineers (4).

2. THE PROJECT

A small group of volunteers supported by the Institution of Civil Engineers in London are continuing work on a project on the lives and works of civil engineers in a series of volumes whose full title is "A Biographical Dictionary of Civil Engineers in Great Britain and Ireland". Two volumes have already been published: Volume 1 (1500 to 1830) in 2002 and Volume 2 (1830 to 1890) in 2008 (5, 6). Work has embarked on a third volume intended to cover the period from 1890 to 1920. It is intended as far as possible to retain the style of the earlier volumes, but changes are required to reflect the period selected for the third volume. It is tempting to assign the movement of engineering change to the more complex organisations that were being established, but the more effort that is put into unscrambling the role of individuals from the organisational structure built around them the more often an individual's contribution can be identified.

Few of the individuals named in these Dictionaries are to be found in other reference books. An interim list for Volume 3 has 1000 potential entries. A significant minority, but less than a 100, of these possible entries have been published in the "Oxford Dictionary of National Biography", which succeeded the century old "Dictionary of National Biography" as the national pantheon in 2004. Its initial 60 printed volumes are now becoming a smaller proportion of an increasing number of on-line entries, which may never be offered in print (7). Engineering biography has different priorities from either the study of entrepreneurs or the selection of individuals for a national pantheon. These priorities partly arise from the long life of many civil engineering works. This heritage makes it useful to both identify the major works of the entries and to establish the identities of their trainees. It is likely that trainees would be influenced by, if not follow, their mentor's approach to design in their own works. This is particularly important for works built before 1920 as design procedures had not begun to be standardised until the Great War (8). Until then it had been the opinion of the Institution of Civil Engineers that such matters as, say, the loads to be borne by new bridges were the individual decision of their designers and need not be the subject of any national consensus (9).

3. THE PERIOD

During the period from 1890 until 1920 there were many subtle changes in the employment of civil engineers world-wide and of the significance of the Institution of Civil Engineers. It was the leading engineering society in Britain and was the model often followed by other similar bodies in both the United Kingdom and elsewhere. More new members joined the Institution in those thirty years than in all the previous years combined since its formation in 1818. The Institution of Civil Engineers is a hierarchical organisation. At that time there were three main categories of member. Students were trainees of between eighteen and twenty-six who were or had been pupils of a corporate member. The largest group were Associate Members who were over twenty-five years old, who had both been educated as civil engineers and been engaged in civil engineering work for at least five years. The third main class was Members who were over the age of thirty who had been employed as a resident engineer or equivalent for at least five years. Above these three layers was the select group of Members of Council. The Council expressed the Institution's official opinions as well as governed its operations and finances.

After 1890 Britain's distinctive commercial feature was not its manufacturing districts, which were individually challenged elsewhere. It was Britain's huge foreign investments that were different (10). The largest proportion of this investment was in mining, which had almost a third, but more than half of the remainder was initiated by civil engineering of railways, tramways, water supply, sewerage systems, etc. The head offices of many of these organisations were in London and their consulting engineers were there too. These were the figures that came to dominate the Council of the Institution of Civil Engineers which sat at the centre of a network that radiated far beyond its headquarters in Great George Street, Westminster.

4. BRITISH INFLUENCE

The Institution had overseas members from almost its start. Corresponding or Non–Resident Members included all members living more than ten miles from Westminster. By 1896 most of the ICE's membership had addresses more than ten miles from Westminster. Half the entire membership lived elsewhere in the British Isles. More than half the remaining members were overseas, almost all in the British sphere of influence, i.e. India, Australasia, Canada and the colonies. The ICE was more than an international learned society it was also a London club for professional engineers. The Council was dominated by London-based consulting engineers. By the 1890s they had identified their own future with the growth of the British Empire and they saw centralised control from London as their key concern (11). When the ICE headquarters building was rebuilt in 1910 its imperial significance and identity was emphasised in the materials used for its construction which came from all corners of the Empire. It was intended to be as much a part of imperial Westminster as the nearby Colonial, Foreign and India Offices.

The control sought by the Great George Street clique was not easily achieved. The overseas members expected some say in matters. They sought to influence the Institution so that their needs and requirements were addressed. They pushed for representation of specific expatriate constituencies on the ICE Council and for the setting up of local Advisory Committees. The small and highly influential group of Westminster-based consultants made concessions in order to retain and develop their connections with the diaspora of British engineers as people who could be called on with strong ties of friendship and obligation to help maintain their own power and authority. This imperialist view withstood and was perhaps reinforced by the trauma of the Great War. In the war's aftermath the leading ICE members would allow the number of their lost sons to be offered as a reminder of their commitment to an imperial vision. Less committed outsiders saw that the independent dominions would become increasingly so - no matter how much wishful-thinking was undertaken and minor concessions were offered in London (12).

5. ENGINEERING OBITUARIES

During the era covered by Volume 2 it was possible for a Civil Engineer to both be innovative in Engineering Science and make an impact in practical business at the same time (13). By the time considered in Volume 3 some early engineering researchers did move on to business, but only a small minority could be classed as innovators. Specialisation and segmentation around maturing technologies were the main trends of civil engineering - with only a few exceptions - in the period. The period covered by the third volume deals with the increasing scale, complexity and specialisation of British civil engineering endeavours. Civil engineers, whose birthplace, education and formative years in the profession were abroad, sometimes relocated to the United Kingdom. All of Ireland was part of the United Kingdom during the period before the creation of the Free State in 1922. Herbert Hoover, later to be a President of the United States was based in London from 1900 until 1917 as a consultant mining engineer.

Membership of the Institution of Civil Engineers is not a prerequisite for entry into the Biographical Dictionary of Civil Engineers, but the membership doubled over the thirty years under review and many of those members are worthy of at least a short mention. The current public interest in genealogy implies that the more individuals researched the better –

especially if, at some future date, it is decided to follow the lead from Oxford and increase the number of entries available on line. Obituaries published in the Minutes of Proceedings reduced dramatically in number during the Great War and as a result this valuable starting–point, which had been available for the two earlier volumes, is not available for many potential entries. On the other hand in the twentieth century there was much more contemporary commercial publication, some of which identifies individual responsibility while others include conflicting claims which need careful scrutiny.

6. ENGINEERING SCIENCE

Most pre–1920 civil engineers did not have university degrees, but academic awareness and theoretical analyses were increasing. This was the first period when engineering professors with full academic careers became ICE Presidents. There was an increased promulgation of engineering science through teaching and texts – a large increase in the publication of handbooks, such as the annual Kempe's, and the emergence of technical standards as part of a wider change in societal infrastructure. This included a wider use of more rigorous testing and the beginning of government sponsorship of central laboratories. The first of these, the National Physical Laboratory, was controlled by the Royal Society with the support of, *inter alia*, the ICE. In 1916 the government set up the Department of Scientific and Industrial Research with a mandate to conduct research on subjects which concerned the community including building and encourage research by industry through research associations and the training of researchers in universities. Many ICE members were to participate in these activities.

These new approaches followed the introduction of new 'scientific' materials and their large scale exploitation. 1890 marked the completion of the Forth Railway Bridge. This project appears in the careers of several potential entries for Volume 3 including Sir William Arrol, Sir Benjamin Baker, A.S. Biggart, Adam Hunter, R.E. Middleton, Sir Ernest Moir, Wilhelm Westhofen, J.E. Tuit, while some, including Allan Duncan Stewart, Sir John Fowler and Sir William Siemens, whose steel was credited at the time with making it possible, were covered in Volume 2. After 1890 rolled steel sections became civil engineer's most used metal structural component. Another civil engineering use of steel was as reinforcement in association with Portland cement, which became the second most used processed material after treated water throughout the twentieth century. The use of concrete and steel in building, the traditional enclave of the architect, was to be a stumbling block for the ICE's Council. In 1900 Royal Institute of British Architects requested the ICE's opinion on collaboration 'in design of certain classes of structure', the ICE response was that 'the practice of the Institution of acting independently in matters within its scope rendered it inadvisable for them to meet the wishes of RIBA in this matter' (14). This attitude led to the establishment of the Concrete Institute and its successor the Institution of Structural Engineers, whose formation was another example of the "institutional proliferation in the British Engineering Profession" (15). The extensive shared interests and personalities in concrete and steel technology result in all structural engineering activities being treated as part of civil engineering in the Biographical Dictionary.

7. LARGE SCALE WORKS

Concrete and steel were also the materials that were to 'scale up the man–made world'. Larger docks and deeper navigation channels were required for much larger merchant ships as well as larger warships in the naval race before 1914. These were complemented by rebuilding British railways for heavier and faster trains as well as more challenging bridge crossings. A whole range of civil engineering techniques began to be developed or transferred from the mining industry to deal with new problems that were to arise in soil mechanics, foundations and temporary works. The organisation of work especially the large–scale munitions projects required for the Great War was to tax many engineers and introduce more of them to the larger–scale of the process industries that marked the twentieth century.

Before the Great War the majority of Britain's huge foreign direct investments in railways, seaports, tramways, etc., employed civil engineers both as home–based consultants and overseas. There, especially in the British sphere of influence, bigger cities worldwide required large–scale utilities often financed by British capital. This extended beyond flood–control, water–supply, sewerage and town–gas, and included centralised electricity generation and distribution. The bulk of the infrastructure for the electric tramways was completed both abroad and in the UK during this period. Another device that began to impact on civil engineering was the motor car. Much was written about the 'dust nuisance' after the dry summer of 1905 and the techniques used to seal traditional road surfaces.

8. WIDER INTERESTS

The larger scale of heavy engineering projects after 1890 encouraged many distinguished engineers whose core discipline was not or had ceased to be civil engineering to both contribute to the ICE and could often be Members of Council. Many of these names appear in the "Oxford Dictionary of National Biography". There are at least 120 whose entry refers to the ICE, but whose interesting lives do not include civil engineering works. The number of marine engineers and naval architects appears remarkable with Sir Alfred Yarrow, Sir William White, Sir Phillip Watts, Sir John Thornycroft, Francis Elgar, Summers Hunter, Sir Henry Oram and Sir Archibald Denny highly placed in ICE's Council. A similar situation occurs with electrical engineers, such as Sir William Preece, M.H.P.R. Sankey, Sir John Snell and, perhaps more surprisingly, locomotive engineers, such as Sir John Aspinall, J.M. Dobson, F.W. Webb, as well as mechanical and steel industry specialists, such as Sir Hay Donaldson, Sir Robert Hadfield, W.H. Maw, Sir Andrew Noble, Sir Charles Parsons, and W.C. Unwin.

Also in this period municipal engineering was evolving from its origins in sanitary science to deal with the problems arising from rapid urban growth. The term "municipal enterprise" was coined. Municipal and County Engineers expanded their activities to include public housing, paving of streets and latterly the construction of new urban roads. This branch of civil engineering introduced techniques, which later became the prerogative of the autonomous town planning profession. Their impact on urban development in the twentieth century was extensive. The successor body for these cross-disciplinary municipal engineers was the Institution of Municipal Engineers, which merged with the Institution of Civil Engineers in 1984, but its heyday was the early 20th. century.

9. ANOTHER GENERATION

The culture of the profession changed within that period and potential conflicts of interest became a greater concern to the public and members. The older members of the civil engineering profession fought a rear–guard action against this. Matters came to a head in 1911 when the 'young Turks' within ICE sought to establish what was to become the Association of Consulting Engineers (16). The group placed the aims and objects of the Association before ICE's Council and a deputation consisting of A.H. Dykes, L.R. Lowcock, W.M. Mordey, J.F.C. Snell and James Swinburne were subject to questions.

The result was an open letter from the Institution of Civil Engineers which questioned the need for a distinction between a 'Civil Engineer' and a 'Consulting Engineer'. The Council's main concern was that the Association would not accept anyone with a concurrent official position and this could in time 'exclude from advisory and consultative work engineers who hold official positions….' whose experience may specially qualify them to give advice on matters with which they are conversant, would be an injustice to them and a serious loss to the public interest' (17). While the Association was concerned about competition for professional engineering work by persons who gained 'their principal emoluments from their commercial or manufacturing interests, and are on that account content to take low fees from consulting work'. ICE's Council formally informed the Board of Trade that they regarded the Association's exclusivity as "a serious loss to the public interest" when the Association of Consulting Engineers sought registration in 1912.

10. THE CASE STUDY

Many such ambiguities and potential conflicts of interest seemed to have been tolerated through much of the period. Individual biographies bring out interesting examples. There follows a case study of Thomas Aitken. He was able to have four concurrent careers, serving more than one master, a 'moral hazard' – but a very effective way of transferring technology.

He had published in engineering journals, including Minutes of Proceedings of the Institution of Civil Engineers in the 1890s, and wrote, probably the best British–published highway engineering book until Collins & Hart in 1936, "Road Making and Maintenance" – first edition in 1900, second in 1907, with an unpublished third edition at the time of his death. He achieved international fame on winning the 1907 Road Improvement Association prize for a pneumatic tar sprayer, which he signed over to a contracting firm, the Taroads Syndicate Ltd of which he was the Managing Director. The fame also led to his services as a consulting engineer most notably to Delaware's duPont family when in 1908 they began to plan a visionary superhighway known as the Coleman duPont Road, along the length of the state.

The Taroads Syndicate gained a reputation of always winning contracts in the county of Fife to the extent that there was no competition for work there. This was hardly surprising as Aitken was the County Road Surveyor and its County Treasurer expressed concern that Aitken alone agreed the quantities of the work undertaken by the Syndicate. When there were complaints at public meetings about the damage to other property by the county's contractors Aitken took the position that the claimant should take the matter with the Syndicate and not the County Council. After Aitken's death in 1918 the next County Surveyor's contract specifically prohibited him from any other paid employment

The whole of Thomas Aitken's life and times is unlikely to be fully told. His surviving writing appears to be either descriptive or promotional. There were no recorded interviews or known diaries. Such information as exists about his life at the beginning of the 20th century arises from the chance survival of correspondence, official archives, newspapers and other publications. It is fortunate that any material survives at all - otherwise another salutary reminder of the contributions of an individual would be lost and with it the lessons to be learned from their trials and errors and, more importantly, how such engineers did achieve results. At the time people seemed to be satisfied with the roads in his care, and mostly ignored his “conflicts of interest”.

The case-study of Thomas Aitken follows as an Annex. It is worth remembering a remark by a one-time mentor, who cautioned that no matter how diligently they are researched the dead can never be fully resurrected.

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Annex A: Case Study
The life and work of Thomas Aitken (1856-1918): an engineer in a developing region.

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SUMMARY OF ANNEX: *This case-study describes the career of Thomas Aitken (1856-1918). He was one of the "silent majority" of British civil engineers, who had little to do with the elites in Westminster with their influential imperial connections. His opportunity to progress four separate careers concurrently was later denied his successor. The case-study demonstrates the complexity of such as Thomas Aitken's life and times whose commercial, political and technical restraints are both different and misleadingly familiar to our own.*

1. INTRODUCTION

Thomas Aitken was born in Edinburgh, Scotland, on 28 February 1856, he was educated at the city's High School and Heriot-Watt College. While at college in 1872 he became an engineering pupil of the North British Railway Company, then Scotland's second largest railway. At the end of his pupilage he became an assistant and then a resident engineer in the northern district of the Company's system, until he was 26 when he was appointed road surveyor of Fife. He was still in that post when he died at the age of 62 on 27 May 1918.

At first sight Aitken's was a simple career, but its longest strand as a paid official was only one of the four strands of a diverse engineering career, which is complex to unravel (1,2). The second strand was as a technical author, which he began at the age of 30 and resulted in texts still in use several decades after his death. His third strand as a consultant began a year later. At the age of 52 Aitken was one of two consulting engineers "of international renown" hired by Coleman duPont, a member of Delaware's leading industrial family, to visit Wilmington to advise on the formation of a visionary superhighway intended to run the length of Delaware, which would be handed over by the family to the state as each ten mile section was completed. The fourth, and nowadays perhaps most surprising, strand began in 1906 when at the age of 50 he became the Managing Director of a road surfacing contractor, which numbered his employers in Fife amongst its customers.

2. THE DEVELOPING REGION

The Fife peninsula lies on Scotland's eastern seaboard. To the north lies the mouth of the River Tay with Dundee on its northern shore. To the south lies the mouth of the River Forth with Edinburgh on its southern shore. Its area is about 1300 square kilometres. The rapid expansion of coal-mining and its supporting industries doubled Fife's population between 1850 and 1900 to over 300,000 (3). Through the 20th century growth continued much more slowly to reach 360,000 of today.

By the late 1850s the peninsula's ports and main centres of population had been linked by a network of local railway schemes that had survived from the many formulated during the 1845 railway mania (4). Few places were more than a dozen kilometres from a railway of sorts. All heavier industry was served by branch railways and from the age of 19 until he was 26 Aitken surveyed, set-out and superintended the construction of short branch lines and tramways to collieries and quarries and latterly superintended additional tracks to the main railways.

Those seven years were momentous times for Fife's railways. In 1879, when Aitken was 23 the newly completed railway viaduct across the estuary of the Tay collapsed. By 1882 work had begun on the replacement for the Tay Bridge and for the even more famous railway bridge across the Forth estuary. At the same time a main east-coast trunk railway line was being formed by upgrading one series of routes between the two major bridges through Fife (5). There is no mention of the large projects in Aitken's papers. In 1882 he did work on a railway bridge across the Forth - but far upstream at Stirling, where a railway line from West Fife added to the collection of bridges beyond the upper limit of navigation. In that year he opted for a seemingly quiet life – but a busy one.

3. THE FIRST STRAND

The busy job was County Road Surveyor. In 1882 the decline of turnpike roads was well advanced as longer distance traffic transferred to the parallel railways (6). The county councils had begun to improve roads for the agricultural and local road traffic which now ran to the railways by the former cross-roads. These cross-roads now led to railway stations. The tempo of development ensured that traffic had very much increased. In the earlier words of a member of Parliament, as railways took over the long distance traffic county roads required to be renewed such that "the veins of traffic (became) arteries, and the arteries veins" (7). Although contractors were sometimes used, the bulk of the manual work in both roads and quarries was undertaken by hourly-paid employees controlled by trusted foremen.

Surviving records indicate that for the first five years of his appointment Aitken concentrated on the tasks before him as a paid official – the first strand of his career. During this time he undertook his most scenic road project, which was also in the best tradition of Thomas Telford's practice (8, 9). His new road ran obliquely down the Garlie Bank, now the A916 south of Cupar, Fife, to "link two valleys to replace a route with gradients as steep as 1 in 10 while saving 1½ miles with a maximum gradient of 1 in 30 suitable for mixed traffic" (horse and traction engine).

4. THE SECOND AND THIRD STRANDS

At the age of 30 he began the second strand of his career - writing what he called "pamphlets" on topics such as masonry bridges and rock-drilling. The third strand of his career as a consulting engineer can be traced to 1887 when he commenced his "concurrent private practice" with a small sewerage scheme for the Burgh of Ladybank.

It was probably with this third strand in mind that he applied for Associate Membership of the Institution of Civil Engineers (ICE) in 1893 at the age of 37. His application made much more of his first ten years with the North British Railway than his subsequent eleven years as a Road Surveyor. His supporters were all from railway organisations (10). Two years later he described his more recent experience in a paper on the maintenance of macadamised roads, which was published in the Minutes of Proceedings of the ICE in 1895 (11).

This seemed to whet his appetite for fully developing the second strand of his career and five years later the first edition of his seminal work was published, "Road Making and Maintenance: a practical treatise for engineers, surveyors, and others with an historical sketch of ancient and modern practice", by the London publisher, Charles Grifffin and Co. Ltd. (12). Griffin was a major publisher then, its extensive catalogue of Standard Engineering Publications included the 20th. edition of "A Manual of Civil Engineering" initiated by Professor William MacQuorn Rankine" – which had been the best established British text to include road-works to date.

Aitken's 456-page text dealt with the issues that concerned county councils, whose responsibilities for highways had increased in scope following administrative changes in the previous decade. In this first edition Aitken described "mixed traffic" as horse and steam traction and dealt with road alignment, bridge - works, stone-breaking and the metalling of roads. Much space was dedicated to the use of machinery for macadamised roadworks. At that time the county councils involvement in macadamised roadworks included local quarrying, stone-breaking, rolling and keeping the surface clean. The latter was important then as bituminous materials were not in routine use. This was soon to change.

Aitken's position in the first strand of his career was enhanced in 1900, when he was elected President of the Road Surveyors' Association of Scotland. In 1902 he also attempted to transfer to senior membership grade of the Institution of Civil Engineers. He failed after re-submitting his 1893 application with brief additions referring to his work in Fife, his being consultancy work for "several County Councils in Scotland and Ireland" and his 456-page book. His list of sponsors had been extended. These now included consulting engineers in Scotland and Ireland, Charles Hogg and Peter Cowan, and the mechanical engineering expert Professor Hele-Shaw, who confirmed the worth of Aitken's book (13). In the following year Aitken re-applied successfully with the additional support of the most important railway engineer in Scotland, Donald Matheson, Engineer-in-Chief and later General Manager of the Caledonian Railway Company (14). Aitken also provided a much more detailed list of both his publications and other works, which included the reconstruction of the main road between Belfast and Lisburn and his detailed planning for one of the last independent railways proposed to be built in Scotland, the un-built Falkland Light Railway.

5. THE FOURTH STRAND

Light railway projects were abandoned as motor vehicles gained popularity. The automobile also enabled Aitken to launch the fourth strand of his career. Motor vehicles brought the "dust problem" to the unsealed roads of Europe during the dry summer of 1905 (15). This problem was addressed by Aitken, who developed a machine to force under pressure tar or other viscous liquid into the surface of the roads to both “overcome the dust nuisance and at the same time add materially to the life of the road”. Aitken’s pneumatic tar sprayer was entered for the UK Road Improvement Association’s prize at an international competition held near Windsor in England, in 1907.

The Road Improvement Association trials were backed by finance provided by the Royal Automobile Club and the Motor Union. The three chosen stretches of road near Windsor were a four mile stretch of Middlesex County Council macadam road from Baber Bridge to the Staines boundary, two miles of flint road between Twickenham and Kempton, maintained by Staines Rural District Council and three miles of gravel road at Ascot under the control of Berkshire County Council (16). The trials took place during the last week in May 1907.

Three other competitors had brought completed machines to the trial, all of these other machines were failures for one reason or other. Aitken entered one of his patent pneumatic sprayers on a Mann undertype steam wagon. It was the only machine that met the stipulated requirements (17). Aitken gained both a gold medal and a prize of 100 guineas.

Aitken transferred his patent rights to the Taroads Syndicate Ltd. From 1906 until his death Thomas Aitken was listed as manager and representative in Scotland for the Taroads Syndicate Ltd., sometimes known as the Aitken Taroads Syndicate. It was among the first tenants of a new office block completed at 29 St.Vincent Place, Glasgow, for the Scottish Provident Institution in a style described as French Second Empire Renaissance. It continues to be one of the prime commercial buildings in Glasgow (18). In 1906 Glasgow had the highest concentration of British Consulting Engineers outside London.

Then the building housed the offices of several influential Scottish engineers who were pioneers of epoch-changing technologies in the early 20th century. These included John Strain, during the second phase of his career, centred on the Lanarkshire Steel Company, who helped initiate the British Standards movement and the subsequent development of the International Standards Organisation and Albert Richard Brown, whose role as intermediary and guide with his connections in Japan were to influence the industrialisation of the Far East (19, 20).

6. EXPLOITING THE TECHNOLOGY

Aitken’s machine was patented not only in Great Britain, but in United States (Patent No. 918,490) as well as France, Germany, the Netherlands, Belgium, Australia, South Africa and other countries. Several of these foreign patents were sold within a few years, while the Taroads Syndicate continued to exploit the technology with plant on his principles sold all over the world. Most machines were on steam wagon chassis, many of them by Mann of Leeds or Aveling & Porter. (21). The last of the Aitken sprayers in Scotland was broken up in the 1950s.

The 1907 trials gave impetus to the tarring of roads and the introduction of mechanical spraying plant for the purpose. When a spraying machine was mounted on a steam wagon steam coils could be used to keep the tar melted, but where bitumen mixes or pure bitumen were used, as happened on a substantial scale from the mid-twenties onward, steam provided insufficient heat and a separate heat source either solid fuel or oil fired had to be provided. Any bitumen boiler, whether equipped with a sprayer or not, needed a double pass flue bringing the chimney to the same end as the firedoor and the furnace was generally larger. In the interwar years a large part of this trade was in the hands of Wm. Weekes & Son Ltd., of Maidstone (17). Their chief designer, Leonard Pearch, bought a map and gazetteer of New Zealand and set himself the target of selling at least one appliance to every road authority in that country – an ambition he did achieve eventually.

7. THE SECOND STRAND - CONTINUED

Also in 1907 the second edition of “Road Making and Maintenance: a practical treatise for engineers, surveyors, and others with an historical sketch of ancient and modern practice”, was published by the same London publisher, Charles Grifffin and Co. Ltd. This edition was 540 pages, 84 pages more than the first edition (22). The extra pages dealt with the attributes of motor cars, citing extensively from, *inter alia*, Professor Hele-Shaw‘s work as well as new chapters on dust prevention and the advances in the analysis of rock for use in road-making.

Shortly before his death Aitken had received the proofs of a large part of a third edition from the same publisher. His books were a source of information for British highway engineers for a surprisingly long time. The people in the north of the Hebridean island of Raasay had no road to link them with the more prosperous south of the island. A petition for a publicly funded cart road failed. Their provisions were brought by boat from the adjacent island, Skye. In 1966 a crofter, Calum Macleod, literally took matters into his own hands. Calum had no experience of road-making. He began by buying a second-hand copy of Aitken’s text. During the following ten years he wore out “two wheelbarrows, six picks, five hammers and four spades” to build a 3-metre wide road, 3 kilometres long comprising a layer of stone, gleaned locally, much of which had to be broken by hand, surfaced with gravel and small stones (23, 24). In 1982 Calum's road became a public highway and £115,000 was spent widening and surfacing it.

Aitken's texts were the primary reference source for professional engineers in Britain until Edward Arnold & Company established their Roadmaker's Library series in the mid-1930s. Aitken's text was hardly cited in any of the series and when it was mentioned it was prefaced as the classic work. The best-selling of their texts was "Principles of Road Engineering" by Professor H. John Collins and C.A. Hart first published in 1936 (25). It cited extensively from American research on roads undertaken in the 1920s. In the early years of the 20th century it was America that sought road-making expertise from Europe.

8. THE THIRD STRAND – CONTINUED

In February 1908, Thomas Aitken made a special request to Fife County Council that he was "desirous for five or six months in the current year of having an Assistant so that he would be able to be absent from the County or otherwise occupied to the extent of about a day and a half in each week during that time and he proposed to employ an assistant whose remuneration would be at the rate of not more than £110 per annum and who would be in attendance in the office in Cupar in Mr. Aitken's absence as well as an assistant in the office work, which had now become of such amount as could scarcely be overtaken by the Surveyor without an assistant or a clerk, and Mr. Aitken stated that he is prepared to contribute to the remuneration of the assistant" (26). The council decided to pay up to half of the sum, i.e. £27.10s, for the services of an assistant to Mr. Aitken for a period not exceeding six months. Aitken's attempt in November 1908 to continue to employ an assistant failed

In the summer of 1908 Thomas Aitken travelled to the United States. Coleman duPont was a member of the American state of Delaware's leading industrial family, an automobile enthusiast, a leader in the U.S. Good Roads Movement, and serious student of roadways. He had travelled throughout Europe and the United States examining road design and construction technology. He offered to construct a visionary superhighway the length of the state of Delaware (27). He planned a multimodal highway design unlike anything that had ever been built. It would have had central lanes for high-speed automobiles, and flanking lanes for trolleys, heavy motor freight, horses and horse-drawn vehicles, and pedestrians. DuPont brought to Wilmington "two consulting engineers of international renown, Thomas Aitken from Scotland and Ernest Storms from Belgium".

The Boulevard Corporation Act, as passed by the Delaware General Assembly in 1911, authorised a corporation, known as Coleman duPont Road, Inc., to construct the highway the length of the state. As each section of ten miles was completed, it was to be conveyed to the state free of charge. DuPont himself was chief engineer. Construction began with the southernmost section in September 1911. Litigation interrupted construction from 1912 to 1915, but the first 20 miles of the road, from the Maryland Line near Selbyville to six miles south of Milford, was completed and presented to the state on May 24, 1917.

Although built to a smaller scale than originally proposed by duPont, the 2- lane concrete highway was still an example of one of the most modern highways in the U.S. at that time. It pioneered the bypass. The highway bypassed towns and was connected to them through spur roads. At first the public thought the idea ridiculous, and worried that it would hurt business. After its execution, the bypass idea took root in the highway department, which said in a 1920 report that "in many instances it is better to have the trunk roads laid out near the towns rather than through the towns" because of concerns for safety and traffic congestion. The highway was so successful as a trunk line for Delaware's rapidly increasing motor traffic, that it soon became overburdened. The widening of what is now U.S.Route 113, began as early as three years following its completion.

9. THE PUBLIC INTEREST

On his return to Fife in September 1908 the Surveyor's official response to damage to property arising from tar-spraying in a village was "that the work of tarring the road was done by contract with the Taroads Syndicate Ltd. And suggested that the letter be forwarded to that syndicate (which was done), with the request that it be dealt with, and nothing further has been heard on the subject" (26). Aitken's personal involvement in the syndicate was no secret, but was not acknowledged in any official documents in Fife. Surface-spraying of roads with tar was credited in the Council's records in May 1909 "of forming "in-situ" Tarmacadam (which) has proved very successful and has been greatly appreciated by those residing in houses adjoining the highway, further work of this nature will be carried out over this summer more particularly in villages through which much wheel traffic passes".

Throughout the period from 1906 until 1910 Aitken continued to publish a series of articles on his system, which was intended to meet the requirements of the highway authorities in Britain to both preserve roads and prevent dust as motor-traffic increased (28-34).

Aitken's annual report to the County Council in 1912 noted that "vehicular traffic is still on the increase, necessitating the application of larger quantities of metalling and the employment of additional labour" (35). He continued "the surface spraying of certain roads with prepared tar has had good effects, and has been greatly appreciated by the occupiers of houses situated near the highways and by travellers generally. It is very noticeable where roads are so treated that the number of pot-holes, caused principally by motor-cars, are practically non-existent compared with untreated portions of roads adjoining. The grant provided by the Imperial Road Board will be principally allocated to making tar-macadam through the villages situated on the "selected routes" and also for surface spraying at different places". At that time Aitken's annual salary as the Road Surveyor was £325.

The Great War had already begun when permission was finally given for the appointment of an Assistant Road Surveyor at an annual salary not exceeding £100 per annum to be paid monthly. In October 1914 the Council members voted whether to appoint William Lindsay who sought £90 per annum or William Boyd who settled for £80 in addition to an annual allowance of £3 "for the maintenance of a bicycle" (35). The vote was 3 to 4 in favour of Boyd.

10. CONSIDERABLE DIFFICULTIES

However the conflicts of interest apparent between Aitken's 1st and 4th strands were becoming more obvious. Lessons about such conflicts, which had been learned in other public works over the previous century, were being learned in Fife (36). In July 1915 the County's Treasurer reported that there were "considerable difficulties in passing accounts incurred to the Taroads Syndicate, certified by the Road Surveyor" (35). The contracts that the Syndicate was awarded had been offered in competition but other contractors seldom submitted bids and if they did they were always undercut.

The Great War also began to intrude. In October 1915, Lord Derby was appointed Director-General of Recruiting. He brought forward a scheme, known as the Derby Scheme for raising the numbers of recruits. It was half-way to conscription. That December, the Assistant Surveyor, William Boyd, was granted an allowance of £2 per month for six months by the Council for joining the army under the Derby Scheme. In the event Boyd's allowance was renewed for four further six-month periods and he was never to work for Thomas Aitken again. At the same meeting Aitken reported that 12 of his roadmen were eligible for military service, but requested that his foremen be exempted from military service on account of their skills being as valuable as munitions workers at home (35). By the end of 1916 Aitken reported that following a further request by the "Imperial Road Board" he had no more men to send to the front.

In early 1916 Aitken received permission for a female clerk to take Boyd's place temporarily at a salary not exceeding £32 per annum paid weekly. This post was taken up by Aitken's 26-years old daughter, Margaret. The Great War took its toll as roads were damaged by the traction engines used to haul off the rapidly depleting woodlands of the county and a Fife quarryman who had joined the Roads Construction Company in France died on October 1917. William Boyd was convalescing after injuries at the front, when on 27 May 1918 Thomas Aitken died.

11. SYMPATHETIC REFERENCE

The local newspaper, *"The Fife Herald & Journal"* reported "in the death at Banchory on Monday afternoon of Mr. Thomas Aitken, there passed away an official of long standing in the county of Fife and of wide reputation in his profession as a road surveyor. To the efficiency with which he carried out his work as road surveyor frequent testimony has been borne. In an article in the 'Fortnightly' some years ago a stranger on a cycling tour told the present writer that in all the counties he had visited he had not come across roads equal to those in Fife" (37).

The paper gave a brief outline of his career including a reference to the formation of the Taroads Syndicate, Glasgow, "with Mr. Aitken as managing director. He subsequently formed a small company for the purpose of working the (tar spraying) machine and accomplished a great deal with it, particularly in the west of Scotland." *"The Fife Herald & Journal"* rounded off its tribute with "A family bereavement that told perceptibly on Mr. Aitken's health was the loss of his younger son, James, who after going through the Gallipoli campaign died of fever in a hospital at Amara, near the Persian Gulf. Mr. Aitken is survived by a son and daughter."

On 4 June 1918 a special committee meeting was called "for the purposes of considering what arrangements should be made by the Council for carrying on the work on the roads following the death of the Surveyor, Mr.Aitken" (35). The whole question was fully discussed and it was ultimately resolved that Mr. George Strachan be asked to supervise the work on the roads in the same way he acted for Mr. Aitken. Mr. Strachan was to be allowed his out-of-pocket expenses and to be given an honorarium when the arrangement with him terminates. It was further resolved to recommend Mr. Boyd be continued as Assistant Road Surveyor and that his salary be increased to £160 per annum."

Aitken's daughter was asked whether she wished to remain on her then salary of £45, but she resigned. It was soon learned that Margaret Aitken had removed various plans and other articles from the Council's office and contended that these had belonged to her father. The Committee believed that the plans were not his property and began formal procedures to recover them. At the same meeting the Assistant Surveyor was authorised to procure any necessary drawing materials required by him and was asked to make an inventory of what remained in the office (35). It was also agreed that arrangements should be made to purchase from "Mr. Aitken's representatives" the engineering level that had been used by him.

In July Major Lawson of Annfield, chairman of the Cupar District of the Council "made sympathetic reference to the death of the late road surveyor of the district, Mr. T. Aitken. He was an enthusiast in his profession and had given very great service to the Committee. He moved that they record their senses of loss in the minutes and send an excerpt to Mrs. Aitken" (38).

12. BACK TO THE USA

In September a motor cycle was provided for the use of the Assistant Road Surveyor at a cost of £48 (35). On 1 April 1919 William Boyd's contract as Road Surveyor was confirmed at a salary of £250 per year rising at £20 per year to a maximum of £400, but he was not allowed to undertake work for anyone else.

Boyd was still the County Road Surveyor for Fife when he took ill and died on 18 July 1952 (39). His successor, Tom McCallum, was a member of the County Surveyors' Society team which visited the United States to study the place of motorways in their transport system (40). McCallum later recommended one of Boyd's sons, also called William, become the Resident Engineer for Fife's first motorway, the M90, which was completed in 1970 (41).

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A Centennial Review of the North Island Main Trunk Railway: Geology of the West-Central North Island and its Influence on Transport Development

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SUMMARY: *This paper is an account of how the geology of the west-central North Island has affected the difficulty of finding the most favourable route for and the building of the North Island Main Trunk Railway. Some subsequent deviations have also been necessitated to some extent by continuing geological processes. Soft sedimentary rocks uplifted from the sea in the past 2 million years have poor competence as engineering materials. Combine this with the original dense forest cover on these rocks and the topography, the whole presented major riddles to builders of transport routes. Apparently easier routes on volcanic deposits to the east of this area proved to be even less attractive to route-finders.*

Implications of geological issues for the Railway are explored. In combination with the "long depression" of the 1880s, they caused progress to be slow until after 1900. Completion of the North Island Main Trunk Line forced the Railways' management to reconsider its objectives, a necessary move towards integrating New Zealand's several regional economies into one national economy.

1. IN THE BEGINNING

The concept of the North Island Main Trunk Railway (NIMT) goes back to Julius Vogel and his immigration and public works policy, first enunciated in late 1869. Inspiration for this came from the principles behind the successful completion of the Union Pacific Railroad that year, the first trans-continental railway across the USA. Vogel travelled it very soon after its opening. Vogel's plan was to bring in migrants who would build public works, primarily railways and roads to open up and provide access to land in the interior. Once those transport links were built, the migrants could then settle on the land and begin to develop it, creating the traffic that would pay for operation and capital loans used for building the links. A network of railways linking the country overland that included an Auckland-Wellington link was central to all this.

New Zealand's North Island at that time had a vast, mostly rough and heavily forested interior largely devoid of Europeans. Isolated European settlements were mostly coastal, though linked by overland telegraph lines and regular coastal mail steamer services. A major complication was the unresolved land wars of the 1860s that left varying levels of Maori disaffection with the Crown across a broad swath from the Bay of Plenty to the New Plymouth and Wanganui hinterland.

Railway construction in the North Island got off to a slow start and progressed slowly. By 1880, Auckland was linked to Te Awamutu, just north of the Puniu River, northern boundary of Te Rohe Potae, "the rim of the hat", more widely known as the King Country, an area forbidden to Europeans 1872-83 by King Tawhiao's aukati that was included in the immediate settlement of the Land Wars. In the east, in 1883, the Wellington-Napier railway was under construction southward to Makutuku in Hawkes Bay and from Masterton to Mauriceville. Three years later the rail route between Wellington and New Plymouth via the Wellington & Manawatu Railway and the Railways Department lines north of Longburn was completed.

In the west and middle of the Island there was Te Rohe Potae, one of the most rugged and difficult to travel through parts of New Zealand. Dense forests added greatly to the difficulty of moving through this area.

2. GEOLOGY OF THE WEST-CENTRAL NORTH ISLAND

See Figure 1. The rocks of this western part of the North Island have some remarkably intractable engineering properties. Oldest, in the north, are of ages varying back to Eocene times up to 56 million years ago (MYA), though these last may be overlaid by younger rocks. They range from limestones through sandstones to siltstones and mudstones that are generally known as "papa", the Maori word for "earth". All were laid down in shallow seas and are cemented with lime.

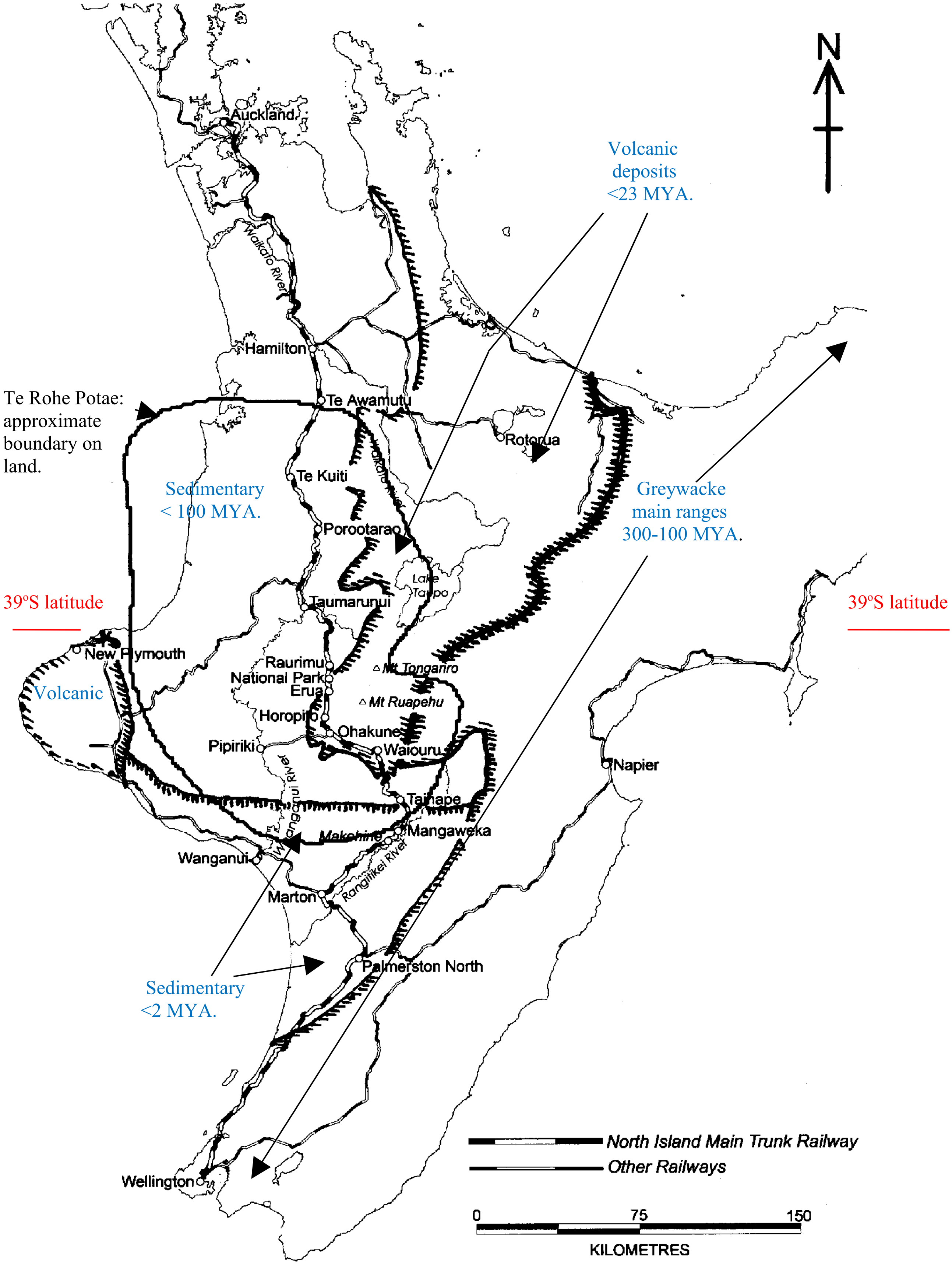

Figure 1: *The North Island of New Zealand, showing the route of the North Island Main Trunk Railway and indicative ages of geological formations.*

Most of these rocks weather rapidly as the lime is leached out or as expansive volcanic clays contained within them change volume with changing moisture content. For many years derivative clay soils barred all progress to horse or wheeled vehicle in wet weather. Durable gravels suitable for use as road metal or railway ballast were only found in the Rangitikei and Whanganui Rivers. Those in the Rangitikei River are greywackes derived from the Kaimanawa and Ruahine Ranges. The upper Whanganui River carries gravels derived from the andesites of the Mts Tongariro and Ruapehu area.

Structurally, the north of Te Rohe Potae is oldest. The Waikato coal measures date to Eocene times. Most of New Zealand was submerged around 20 MYA. Until about 2 MYA, the North Island south of about latitude 39^0S (a line through Waitara and Turangi) was almost entirely submerged until uplifted with the rise of the present Tararua and Ruahine Ranges. Visual evidence of this may be seen in features such as the reversal in direction of the Whanganui River at Taumarunui; the conforming directions taken by all the southward flowing rivers in this region as they followed the fall of the land as it rose; and the very prominent terraces along the valley of the Rangitikei River. Terraces are indicative of pauses in the uplift process.

Volcanism over a long period is a major feature of the North Island, with andesitic mountains such as Ruapehu and Tongariro dominating large areas. To the north and north-east of them, the volcanics of the Rotorua-Taupo series have wrought dramatic changes from about 1.7 MYA, blanketing extensive areas with ignimbrite, pumice, and derivative clays known as “brown ash”.

3. FINDING A PRACTICABLE ROUTE FOR THE NIMT RAILWAY

The geology of the west-central North Island was all significant to transportation route-finders, as it remains to those who must maintain routes through the area.

The first serious attempt to find a route for the NIMT came in 1873 when John Carruthers explored east of Te Rohe Potae, following the Waikato River from Cambridge to Taupo, then passing east of Lake Taupo and across the Rangipo Desert to about present-day Waiouru. The route was beguilingly attractive, being largely covered in scrub and fern, with generally favourable geology, topography and gradients. Almost all of this route crossed topography and soils derived from Taupo volcanic zone eruptions. Unfortunately, much of the soils crossed en route proved to be un-farmable due to bush sickness. It was only in 1936 that this fatal ailment of farm animals was traced to the deficiency of cobalt in pumice soils. The summit of this route at the Rangipo Desert was found to be some 300 metres higher than its equivalent on the western side of the volcanic plateau, further lessening its relative merits.

When negotiations between the government and leaders of Ngati Maniopoto and Ngati Tuwharetoa led to a settlement agreeing to route-finding surveys for a north-south railway at the beginning of 1883, four general routes were explored. See Figure 2.

G P Williams surveyed a Te Awamutu-Napier route up the Waikato River and along that now taken by State highway 5, the Napier -Taupo road. He concluded that this indirect route was not practicable for a railway owing to its very high summit and steep grades on the descent to Hawkes Bay.

C W Hursthouse was chosen to survey from Te Awamutu towards Stratford. After facing great difficulties with some Maori, he concluded that a railway to New Plymouth via Mokau was feasible. This route is now taken by State highway 3. A second round of exploratory surveys was then carried out in 1884 by R W Holmes and M Carkeek, examining possible routes from the north to Stratford and to Waitara. Feasible, though difficult, routes were found.

John Rochfort undertook exploration of the central route, from Marton to Te Awamutu by way of Ohakune and Taumarunui. He began on a route suggested by H C Field and explored by J F Sicely in 1882, following the Porewa, Rangitikei and Hautapu rivers to reach Ohakune. Rochfort continued this work northwards across the volcanic plateau to today’s National Park township, then down the Piopiotea and Whanganui Rivers to Taumarunui. From Karioi northward he met considerable Maori opposition and non-cooperation that was to have consequences later when the descent to Raurimu was explored in more detail by location engineers. From Taumarunui northward, Rochfort’s route continued to be that of the NIMT as built, passing up the Ongarue and Ohinemoa Rivers to Poro-o-tarao, then downhill to Te Kuiti and Te Awamutu.

In autumn 1884 the Minister of Public Works, Hon E Mitchelson, who had travelled the two most likely routes, concluded that Rochfort’s central route was the best for the NIMT. It was the most direct, the route was almost entirely through millable forests, and most of the country traversed could be farmed once the forest had been cleared.

Mr Mitchelson expressed the view that it would be difficult to find an easier route that could be built for £3,100 per kilometre. That budget level, set under the Vogel scheme some 14 years earlier, was unrealistic by 1884, especially so in view of the nature of the terrain in Te Rohe Potae. The original moving structure gauge and clearances of 1870 were being increased to accommodate increased traffic on open lines. Stations

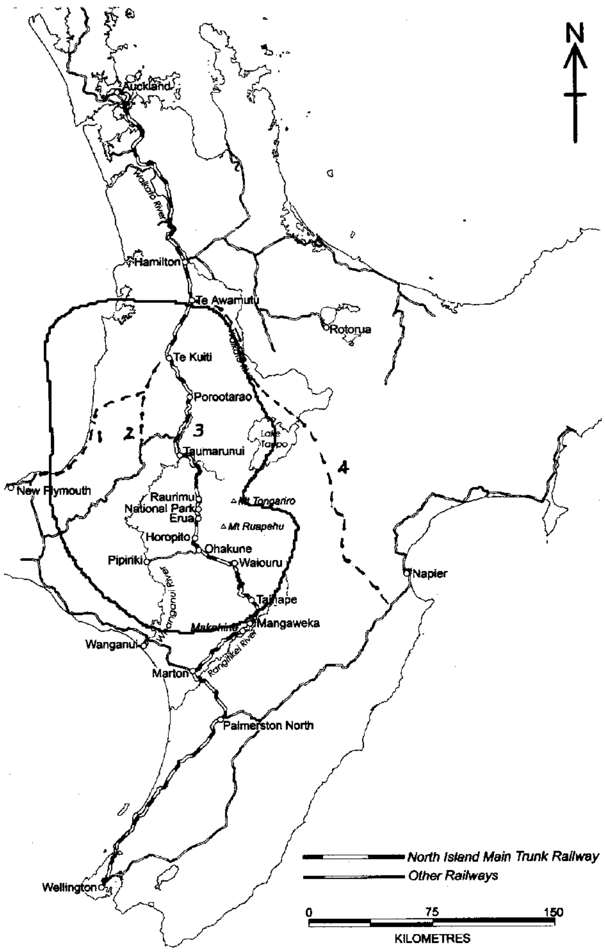

Figure 2: *Route finding surveys for the NIMT. Western routes 1 and 2 surveyed by R W Holmes & M Carkeek; route 3 by J Rochfort; and route 4 by G P Williams.*

and yard facilities were more extensive, minimum acceptable curves radii for main lines had been increased by 50% to 150 metres; standard rail weights had been increased by 40% to suit increased locomotive axle-loads; and bridges were being built of Australian hardwood instead of the weaker, but available at the lineside, native timbers. Also, labour and materials prices had increased.

The northern descent from the volcanic plateau, from National Park, has always been the critical part of the NIMT route. Finding a practicable route took from 1887 until 1898, and the final decision to adopt the route built was only taken in 1900. R A Brown and G B Beere began explorations for a workable route graded at 1 in 70 as thought possible by John Rochfort, in 1887. Three survey lines were all abandoned in very rough country as impracticable. John Blackett, Engineer-in-Chief of the Public Works Department 1884-90, opted to increase the maximum design grade to 1 in 50. (Blackett was also at the centre of the Government's March 1871 decision to adopt our standard 3'-6" (1067 mm) track gauge.)

A further survey by J B Browne and C B Turner found a very expensive route on this grade that would entail nine viaducts with an aggregate length of 1.3 kilometres. Two other trial surveys at 1 in 50 are known to have been made, and a fourth possible route appears to have been briefly considered.

The difficulties and estimated costs of the routes explored thus far were such that in 1888 two more western routes to Taranaki were investigated. The westernmost, to Waitara, would open no land considered suitable for settlement until it reached the coast. The second was similar to today's Stratford-Okahukura Line, except that it went from Ongarue to Ngaire (south of Stratford). Both would be indirect and expensive to build and operate. The final decision on what route to adopt was still 12 years away.

The combination of tectonic uplift and erosion of soft rocks forcing rivers into an uncertain drainage pattern, and the very dense forests similar in nature to that shown in Figure 3, were a railway route-finder's nightmare. The west-central North Island of the time was incredibly difficult to travel through by present-day standards. Maori used either footpaths or canoes on the rivers. Footpaths could be widened sufficiently for horses to be used, either to ride or to carry supplies as pack animals.

Figure 3: *Hapuawhenua valley with regenerating bush indicative of the roughness and original cover throughout the west-central North Island.*

Geological features proved helpful in locating and building the southern climb to Waiouru. Mr Field had recognised that the several terraces that persist for considerable distances up the Rangitikei and Hautapu valleys to a point beyond Taihape offered an even and easily constructed gradient for a railway. Problems arose where these terraces were interrupted by side valleys, as at Makohine or Mangaweka, or where they ran out, as between Mangaweka and Utiku. John Rochfort capitalised on these advantages, though at a cost of needing large viaducts and extensive tunnels, respectively.

Subsequently, further geological problems in this area have revealed themselves.

The Hautapu River, which is still cutting downward at a rapid rate, has generated very large block landslides that move towards the river as their toe support is eroded. Best known active slides are one across the NIMT and State highway 1 immediately south of Utiku village and another underlying the southern part of Taihape township. Considerable effort has gone into stabilising these as far as can be achieved. Many other such slides have been identified as inactive at present.

A more dramatic phenomenon comes from the release of triaxial stresses in the free face at the papa cliffs of the trenches being carved by the rivers. The rock is in a state of compression arising from its formation under the sea and subsequent burial. Release of that compression at a free face generates horizontal tension that pops slabs of rock off the face of the cliff. In conjunction with scour and weathering, this is a major reason for the clean white vertical faces to be seen in this area. Retreat of the western cliff along the Rangitikei valley had progressed sufficiently rapidly that the five tunnels parallel with it north of Mangaweka were becoming endangered. Tunnel 11, named Black with good cause for its gradient, sharp curve and confined size, was the most endangered: how long would it remain stable and safe under the weight of trains? At some time the retreat of the cliffs will expose and eventually undermine those tunnels. A major deviation to the other side of the valley bypassing this part of the line had to be built 1971-81 to forestall the risk to rail traffic becoming unacceptably high.

Figure 4: *Cliffs and terraces of the Rangitikei Valley as used for locating the NIMT for easiest construction and gradients. River bed greywacke gravels are one of the few sources of competent rock in this part of the North Island.*

4. CONSTRUCTION OF THE NIMT RAILWAY

Access for the early stages of railway construction was by road, as far as possible. In the south, a route had been formed from Marton to Tokaanu as early as 1894. This was metalled from the Rangitikei River (sole source of suitable gravels until those originating from Mt Ruapehu were reached), initially using packhorses to carry the material up the Hautapu valley and through the site of Taihape. S G Laurenson, writing in "Rangitikei: the days of striding out", a history of Rangitikei County, records how the first means of land transport in the County was packhorses and bullock-drawn sledges. Bullocks were stronger but slower than horses and had more stamina under difficult conditions. Metalling of the main road through the County, now State highway 1, to make it adequate for coaches and horses was completed in 1906, two years after the first train reached Taihape. Thirty years later, some County roads were still being given their first applications of road metal.

Bruce Dobson, in his unpublished paper "Road Access a Burning Issue for Settlers of Inland Taranaki" (2003), quotes "History of Whangamomona County", edited by J Garcia (1940), "*Keeping the clay roads at all passable for bullock teams was a difficult matter. In the winter the worst places had to be "corduroyed" with split slabs, or "fascined" with scrub, and even then bullocks got bogged, some even having their necks broken. In the dry weather these deep ruts dried up and became almost impossible to negotiate.*"

One effective but laborious and expensive option which first appears to have been used in the northern Wairarapa and subsequently elsewhere from 1894, was to set up an impromptu kiln at the roadside to burn papa to a brick-like substance that has proven remarkably durable in road pavements.

Until railways were available to transport durable river gravels into the interior, progress on improving and weather-proofing roads was painfully slow. Into the 1950s, North Island hill country roads commonly were closed to heavy motor vehicles through each winter. In this period, and when roads were passable, axle-loads for heavy vehicles were restricted to maxima as low as 3.6 tonnes (2.5 tonnes for axles spaced 1.0-2.4 metres apart) for Class IV loading. As road pavements and trucks improved after about 1950 more extensive metalling programmes gradually brought roads to a reliable condition. Even so, and as late as 1980-85 I recall long debates between National Roads Board staff and rural councils as we tried to persuade them that they could lift Class II load limits to Class I and could rely on the Board to fund any increase of maintenance needs.

Similar problems were encountered at the northern railhead. For example, the contractor for the construction of the Poro-o-tarao tunnel envisaged bringing equipment, materials, and stores in 70 kilometres from Te Awamutu by water using the Waikato and Waipa Rivers to Pirongia, thence by dray through existing bridle tracks. He was successful in bringing some machines and materials to Te Kuiti by barge, though with great difficulty. Sledges had to be used from there. The government began building a road along the route in 1885, the year the tunnel contract was let. As many as 30 bullocks, supplemented by block and tackle, were needed to drag loads up the hills. Wagons went up to their axles in mud. Stores were mainly transported up-country by packhorse. The remarkable achievement was that the tunnel was completed seven years before the railhead reached it. R J Seddon, Minister of Public Works in 1892, commented during a site inspection, what a waste of public money the transport costs for this contract had been in the absence of a usable railway.

Similar transport problems were encountered when preparations began for the construction of the major steel viaducts crossing the deeply incised streams flowing off Mt Ruapehu (between Makatote and Ohakune). The original plan was to ship steel and other materials up the Whanganui River to Pipiriki, then to transport them to site by road using steam traction engines. The road was built but weather and mud defeated the traction engines: the Minister of Public Works was taunted in Parliament over the number of weeks it took to get each load through by this means. In the end, steel for the viaducts was fabricated in factories established at Makatote and Mangaonoho (originally built for construction of Makohine Viaduct). Permanent and temporary railways were used for transport to site as much as possible, also horse teams on a very well built road from Ohakune to Oio, until the construction railhead advanced further.

The story of R W Holmes' brilliant work in devising the Raurimu Spiral has been told many times before, as in R S Fletcher's book "Single Track". Holmes' 1898 surveys found a practicable means to drop the NIMT off the volcanic plateau. Until construction reached there, all aggregates and ballast had to be hauled from the Whanganui River at Kakahi. This had considerable implications as the railhead extended southward. Much of the haulage capacity of the small and obsolete Public Works Department locomotives was being taken up hauling materials, so that in 1906 the PWD bought two locomotives to the design of the Railways Department's new 44 tonne "Wf" class to supplement them. Another consequence was that Taumarunui remained the Railways Dept's railhead for almost five years, December 1903-November 1908.

Once construction reached the volcanic plateau andesitic gravels became accessible. The problems of transporting materials to the construction work eased greatly, so that the Railways Department railhead could advance 58 kilometres southward from Taumarunui, to Erua.

Construction of the earthworks for the NIMT was almost entirely by manual labour. The first steam shovels were imported to the work in 1906.

Cuttings were mostly excavated in a single face from each end. Horse-drawn end-tip wagons were used to carry the spoil away. These were either loaded directly at the face or through a "chinaman", a wooden platform with a hatch in it directly over the rail track used by wagons.

R S Fletcher records in his book "Single Track" that the contractor for the Te Kuiti-Puketutu section, J & A Anderson Ltd., was caught by a bad winter. The walls of completed cuttings collapsed under the wet conditions, "taking the hopes of a good profit from the job with them", as Mr Fletcher put it.

Embankments were formed by end-tipping from formation level. This method of construction was not conducive to good compaction of the tipped material, so embankments could continue to consolidate over a long period and were at risk from slumping during wet weather. One hazard to the workmen was that if wet papa stuck to the bed of the tipping wagon, load, wagon and all went over the tip-head. Recovering the wagon was usually a laborious and slow task.

Drilling for shot-holes in tunnels was originally by hand, using hammer and steel. I have no evidence of the method used for the NIMT tunnels, but this is the likely method used. Later, when air powered tools became available, coal augers were used to drill shot-holes in papa. These certainly were used for the tunnels on the railway between Napier and Gisborne. There, one hazard was that when the auger bit into a concretion in the rock, suddenly it was the drill that rotated, throwing the man handling it off his feet.

Formation in swampy ground was built in one of two ways. If possible, an earth embankment was tipped to displace the peat and to reach a base on solid ground. This was easier and surer if the swamp could be drained.

In the extensive and deep Waikato swamps floating formation was built on fascines laid transversely to the formation. These provided a base upon which an embankment could be built. Manuka was preferred for the fascines, as it didn't rot when placed under water. The track had to be centrally placed on floating formation lest the whole start to capsize under any unbalanced weight of trains. (This last phenomenon is clearly visible on some rural roads between Hamilton and Morrinsville.) It also had implications when formation widening was carried out by Railways in the early 1980s to carry the masts for the NIMT electrification. As one County Engineer complained to me, he was told to expect a stated quantity of sand to be carted to worksites using his roads. "Then the [unmentionable word describing the contractors] carted twice as much!" I knew why.

5. PRACTICALITIES AND POLITICS

The NIMT took over 23 years to complete between Te Awamutu and Marton. The length of this period related primarily to the economic circumstances of the colony. The Vogel loans monies dried up following the collapse of the City Bank of Glasgow in 1878. Export demand for products such as building timber, wool and grain became uncertain and prices poorer.

New export commodities took time to build up. New processes such as refrigerated transport by sea began to contribute after the first successful shipment of frozen meat in 1882. Production of the centrifugal cream separator from 1874 in conjunction with refrigerated shipping led to a new export trade, in butter and cheese, that was going to serve New Zealand well. In the meantime, the 1880s was a hard decade, in the middle of the "long depression" – some 15 years. No wonder progress on the NIMT was so very slow: the governments of the time were very short of cash and financially conservative by nature.

Change in this began following the election of a Liberal Government in 1891. They set out to reinvigorate the economy by breaking up the large wool-producing grazing leases that blocked higher production from the land in many parts of New Zealand. More intensive settlement, the rise of arable farming to succeed the graziers, and better market prices all combined to create an economy within which the government would have the revenue to fund completion of the NIMT. Strictly speaking, these political moves affected the NIMT only to a minor extent, as it was extending through largely virgin forest. Small farmers, running dairy cows and sheep, came in slightly ahead of or following the railway. Large grazing properties running merino sheep for wool had occupied the tussock-lands east of Mt Ruapehu and north of Taihape since the 1850s. Their access and business links came from Hawkes Bay via the Gentle Annie route. They switched to transporting the wool clip by rail from Taihape when the state of the roads made this possible.

R W Holmes' finding of a practicable northbound descent from the volcanic plateau from National Park to Raurimu helped create a political atmosphere within which completion of the NIMT was seen to be desirable and feasible. The 1900 Royal Commission firmly opted for the route that was built, over alternative western routes through inland Taranaki. (The building and operation of the Stratford-Okahukura Line exemplifies the great difficulty of running a rail route through inland Taranaki. This was opened in stages 1902-33.) After 1900 New Zealand was literally booming, so construction funding, especially with completion visibly drawing closer, came easier.

6. CONCLUSION

The engineers clearly made up their minds on which route to adopt with certainty. They knew how to overcome the technical difficulties, it just remained to gain political support and hence funding to complete the unfinished part of the work.

The 1900 Royal Commission adopted completely the recommendations R W Holmes presented under PWD auspices, passing them on to the Government. The central route was 82 kilometres shorter than any alternative, had 344 metres less of rises and falls, had consistently easier gradients, and avoided the need for Main Trunk traffic to travel through the heavy gradients between Palmerston North and Hawera (the part of which east of Wanganui has since been deviated through long tunnels under the worst hills). The NIMT was the only way of tapping the timber resources of the Waimarino forests, of giving access for settlement and farming of the land all along its route to the benefit of the country as a whole, and of providing reliable, speedy transport and communication through the heart of the North Island.

An apparent oddity of the opening of the NIMT was the seeming lack of enthusiasm of the Railways Department senior management for its new trunk line. Ian Bullock writing in "The New Zealand Railway Observer" comments that it was a route for long-distance transport completed at a time when there was no demand for the long-distance carriage of freight on land. Formerly, Railways' task had focussed on linking hinterland with (usually the nearest) port, from which coastal shipping carried produce to an export port. Their first sign of a change of thinking may be seen in the strategic pricing designed to make Waikato coal railed south competitive with West Coast coal brought by sea to the lower North Island.

Figure 5: *Construction complete, trains were able to link north and south with the first reliable means of transporting freight and passengers overland.*

The opening of the NIMT really did mark a watershed in the development of New Zealand transport. It was a big step in bringing the country together as one commercial entity, in its own time as significant as the institution of roll on-roll off ferries across Cook Strait.

7. ACKNOWLEDGMENTS

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Thank you, too, to John Whibley, for drawing the map upon which I have based mine.

Rob. Merrifield,
22 October, 2009.

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The History of High Voltage Direct Current Transmission

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SUMMARY: *Transmission of electricity by High Voltage Direct Current (HVDC) has provided the electric power industry with a powerful tool to move large quantities of electricity over great distances and also to expand the capacity to transmit electricity by undersea cables.*

The first commercial HVDC scheme connected the island of Gotland to the Swedish mainland in 1954. During the subsequent 55 years great advances in HVDC technology and the economic opportunities for HVDC have been achieved.

Because of the rapid development of HVDC technology many of the early schemes have already been upgraded, modernised or decommissioned. Very little equipment from the early schemes has survived to illustrate the engineering heritage of HVDC. Conservation of the equipment remaining from the early projects is now an urgent priority whilst the conservation of more recent projects, when they are retired, is a future challenge.

1. INTRODUCTION

At the beginning of the electricity supply industry there was a great battle between the proponents of Alternating Current (AC) and Direct Current (DC) alternatives for electricity distribution. This eventually played out as a win for AC, which has maintained its dominance for almost all domestic, industrial and commercial supplies of electricity to customer.

As the size of electricity supply systems increased several major challenges for AC systems emerged. There were major difficulties in increasing the voltage (and hence capacity) and the range of under-sea cables. Also the development of very large hydro-electric projects in areas quite remote from their load centres became an increasing challenge for AC systems to transport vast quantities of electricity over very great distances. For very large transmission schemes High Voltage Direct Current (HVDC) is both more efficient and has a greater capability than AC systems. It was recognised as early as the 1920's that there were advantages in the use of DC transmission systems for these more challenging applications. Hence the concept of HVDC emerged, however development was held back by the lack of a suitable technology for the valves to convert AC to DC and vice versa.

In the late 1920's the mercury arc rectifier emerged as a potential converter technology, however it was not until 1954 that the mercury arc valve technology had matured enough for it to be used in a commercial project. This pioneering development led to a number of successful projects. However at the same time a new technology, the silicon semi-conductor thyristor, began to emerge as a viable technology for the valves of HVDC systems. The thyristor valve first came into use in HVDC applications in 1970 and from that time forward the limitations of HVDC were largely eliminated.

The technology is now mature and experiencing rapid increases in the voltage, power carrying capacity and length of transmission lines. This has occurred at a time when the efficiency of electricity supply systems is under great pressure due to Greenhouse Gas considerations whilst the development of large hydro-electric schemes is an imperative to decrease the reliance on fossil fuel power generation which produces a large proportion of the planet's Greenhouse gases.

2. TERMINOLOGY

The following terminology and abbreviations are used in this paper:

- AC (alternating current). A system of electrical energy where the voltage fluctuates around earth potential in the form of a sine wave at a frequency of 50Hz or 60Hz in typical electricity distribution and transmission systems throughout the world.

- DC (direct current). A system of electrical energy where the voltage remains constant over time and is either positive or negative with respect to earth. This system is used universally in motor vehicle electrics, small devices operated from batteries and in many industrial applications. It is also used in HVDC systems for specialised high power, long range transmission of electric energy. In this paper when the symbols +/- are used in association with DC voltages it signifies that the system operates with one pole above earth potential and one pole below earth potential with the mid-point (zero voltage) at earth potential.

- kV (Kilovolt). The Volt is the SI unit of electromotive force. The kilovolt is one thousand volts and is the commonly used unit for voltage in high voltage electricity supply systems. Domestic electricity supplies operate between 120 and 240 volts depending on national standards.
- MW (Megawatt). The Watt is the SI unit for power. The Megawatt (one million watts) is the measure commonly used for large systems in the electricity supply industry. One MW is equivalent to 1340 horsepower.

Three types of converter devices have been used in HVDC schemes to date and are referred to in this paper:

- Mercury Arc Valves. A mercury arc valve consists of an evacuated chamber containing a pool of mercury at the bottom forming the cathode. The anode is a carbon electrode at the top of the chamber. When the mercury pool is heated an arc can be struck within the chamber which conducts electrons from the cathode to the anode but not in the other direction. Hence the device operates as a rectifier. The device was invented by Peter Cooper Hewitt in 1902. The mercury arc valve was the technology used to convert AC to DC and vice versa in HVDC schemes until the introduction of the semi-conductor thyristor, applied to HVDC schemes from 1970.

- Thyristor Valves. The thyristor is a silicon solid-state semiconductor device with four layers of alternating N and P type materials. They act as bi-stable switches, conducting when their gate receives a current pulse, and continuing to conduct as long as the voltage across the device is not reversed. In HVDC applications many devices are placed in series/parallel configurations to achieve the desired voltage and current ratings.

- Insulated-Gate Bipolar Transistor (IGBT). The IGBT is a three-terminal silicon semi-conductor device, noted for high efficiency and fast switching. The IGBT is a Voltage Source Converter (VSC) meaning that it can be switched off as well as on by gate control. This brings advantages to the control of HVDC valves using IGBT technology. The IGBT is a fairly recent development, first appearing in the 1980's. Third-generation devices were available in the 1990's and quickly gained a reputation for excellent ruggedness and tolerance of overloads. In HVDC applications many devices are placed in series/parallel configurations to achieve the desired voltage and current ratings.

3. THE PIONEER WORK - MECHANICVILLE

In 1932 the General Electric Company built an experimental HVDC scheme between a hydro-electric power station at Mechanicville, New York and Schenectady, New York, a distance of 37 km. This system used mercury arc rectifiers to create the DC voltage but the load at Schenectady was DC motors so in a sense it was only half of a full HVDC scheme which typically consist of a connection between two AC systems. The line operated at 12kV and had a capacity of 5MW. The General Electric Company did not, surprisingly, pursue this technology and the scheme was dismantled after World War II without further development.

4. THE EARLY ENGINEERS

In Sweden in 1929 Uno Lamm, working for the Swedish electro-mechanical company ASEA took out a patent on the high voltage mercury arc valve. An experimental valve, tested in 1933, confirmed the validity of Lamm's earlier patent although it had only a very short life. Research then continued to improve materials to give the valves a longer life. In 1944 a test rig of 2000kW capacity operating at 60kV, proved successful. Lamm continued in the field working systematically towards the goal of a commercially viable system for HVDC.

August Uno Lamm was born on 22 May 1904 at Gothenburg on the Swedish west coast. He studied at the Swedish Royal Institute of Technology in Stockholm and obtained a degree in Electrical Engineering in 1927. After military service he joined ASEA and in 1929 was made the manager of a project to develop the high voltage mercury arc valve. He obtained his Ph.D. from the Royal Institute in 1943, studying part time, whilst he continued his work on the mercury arc valve.

In 1955 he was made head of the project to build Sweden's first nuclear power reactors. In 1961 he was appointed to head the ASEA team in the joint venture with General Electric in the United States to build the Pacific DC Intertie and moved to Southern California in 1964.

During his career Lamm took out 150 patents and wrote 80 technical papers. He wrote extensively and was published widely in the Swedish press on subjects as diverse as societal commentary, education, technology, political commentary and economics. He was strongly anti-communist and anti-Nazi which got him into some difficulties during World War II when he was required to work on ASEA projects in Germany.

In 1973 his portrait was hung in Gripsholm Castle on the outskirts of Stockholm. In this he joined the King and Queen of Sweden and many of his distinguished countrymen who are thus honoured for the credit and recognition they have brought to Sweden.

Lamm received many awards including the Gold Medal of the Swedish Academy of Engineering, Knighthood of Sweden's Royal Order of Vasa, France's Ordre du Merite pour la Recherche et l'Invention and the IEEE Lamme Medal. The IEEE Power Engineering Society established the Uno Lamm High Voltage Direct Current Award in 1981.

Lamm learned to play the violin as a child and retained an interest in the performing arts throughout his life. He was married twice and had four children. He died in June 1989 and is best remembered as the Father of High Voltage Direct Current.

There were of course many other eminent engineers involved in HVDC. Two, who made speeches at the celebrations of the first 50 years of HVDC at Visby, Gotland in June 2004, must be mentioned.

Lennert Haglöf joined ASEA in 1954 and became involved in HVDC in 1962. Before he left engineering in 1987 to join the Group Management Staff he had been intimately involved in the design, installation and commissioning of a number of HVDC projects, including Sakuma in Japan, the Pacific DC Intertie in the USA and Itaipu in Brazil.

Per Danfors was active in HVDC from 1960 to 1980. During the Mercury Arc Era in the 1960's he spent seven years working on the Pacific DC Intertie from concept to commissioning and during the 1970's he was involved in launching the Thyristor Valve Era up to and including the Itaipu project.

5. FIRST COMMERCIAL PROJECT – GOTLAND 1

Lamm's efforts were finally realised in 1954 when the island of Gotland off the east coast of Sweden was connected to the mainland by a HVDC scheme. The Gotland 1 project operated at 100kV and consisted of 98km of under-sea cable between Västervik on the mainland and Ygne on the island. The valves were of the mercury arc type which Lamm and his team had spent 25 years developing. The initial scheme had a rating of 20MW.

The Gotland scheme, generally considered to be the first truly commercial scheme in the world, also became the test site for a series of new technology breakthroughs in the development of HVDC. This site is therefore the most significant heritage site in the development of HVDC for several reasons.

From the commissioning of the Gotland scheme ASEA (later to become ABB) pursued commercial success with the HVDC technology, and have remained the leaders in the field ever since. After the success of the Gotland 1 scheme HVDC did not immediately become an unreserved commercial success for ASEA. Many potential customers were concerned about the possible fragility of the mercury arc valves although history showed that the complex technology was remarkably robust. ASEA implemented six projects from Gotland 1 in 1954 to the Pacific DC Intertie in 1970 using mercury arc valves.

In 1970 the Gotland scheme was re-engineered to 30MW and 150kV using the first thyristor valves to be used in a HVDC application. The original mercury arc valves remained in service alongside the new thyristor valves proving, not for the last time, that the two technologies could work harmoniously together.

The arrival of the thyristor valve was the key to large-scale commercial development of HVDC schemes throughout the world.

6. THE MERCURY ARC VALVE ERA

During the Mercury Arc Era eleven schemes were built. The first was Gotland 1 in 1954 and the last was Kingsnorth in 1972. These schemes spanned the world with one in New Zealand, one in Japan, three in North America and six in Europe.

In 1961 a Cross Channel HVDC link was built between France and England. This project consisted of a 64km undersea cable and converter stations at Echingen in France and Lydd in England. The system operated at 100kV and had a capacity of 160MW. The system was shut down in 1984 after only 23 years service. The main contractors were CGEE Alsthom on the French side and English Electric (later GEC) on the United Kingdom side.

The Konti-Scan 1 scheme, commissioned in 1964, between Denmark and Sweden was a 250kV, 250MW link consisting of 87km of undersea cable and 89km of overhead line. The scheme is still in operation, however the mercury arc valves were replaced with thyristor valves in 2006. This scheme was built by ASEA.

In 1964 the Russians built a HVDC scheme known as the Volgograd-Donbass scheme with its terminal stations at Volzhskaya and Mikhailovskaya. The scheme operated at +/-400kV, a very high voltage for this time, and had a capacity of 750MW. The transmission was all overhead line over a distance of 475km. It is known that this scheme has been modernised with thyristor valves but it is now operating at only 25% of its design capacity. The manufacturer of the original equipment is not known to the author.

The French Mediterranean island of Corsica and the Italian island of Sardinia were connected to the Italian mainland by a three-converter scheme in 1965. The scheme operated at 200kV, 200MW consisting of 304km of undersea cable and 118km of overhead line. The scheme is still in operation, however the mercury arc valves were replaced with thyristor valves in 1986. The main contractors were English Electric for the Italian converter stations and CGEE Alsthom for the Corsica section.

Also in 1965 an unusual project was commissioned in Japan. In this project at Sakuma the two converter stations are on the same site and the HVDC scheme operates as a frequency converter between 50Hz and 60Hz sections of the Japanese AC Grid. The system operates at 125kV with a capacity of 300MW. The scheme is still in operation, however the mercury arc valves were replaced with thyristor valves in 1993. The main contractor was ASEA but when the scheme was later upgraded to thyristor valves the contractor was Toshiba.

A third system, in New Zealand, was commissioned in 1965 between Benmore on the South Island and Haywards (near Wellington) on the North Island. This operated at +/- 250kV with a rating of 600MW initially although it was upgraded later. The transmission system consisted of a 40km undersea cable and 535km of overhead line, mostly on the South Island. The scheme is still in operation and has mercury arc valves still in standby service working alongside newer thyristor valves added in 1991. This scheme was built by ASEA.

In 1968 a scheme known as the Vancouver Island scheme was commissioned between Delta and North Cowichan in British Columbia, Canada. This was a 260kV, 312MW scheme consisting of 42km of undersea cable and 33km of overhead transmission line. The scheme was upgraded with thyristor valves in 1977. The main contractor was ASEA. This scheme has now been replaced by an AC transmission system, however the HVDC scheme is being kept available for service during the early years of operation of the AC system.

In 1970 the Pacific DC Intertie was commissioned in the United States. This project was developed in several stages starting at +/-400kV and 1440MW but finally rising to 500kV and 3100MW. The scheme was entirely overhead lines but over a great distance, 1362km between hydro-electric power stations in the state of Oregon and the load centre in Los Angeles, California. This project started with mercury arc valves but these were later changed to thyristor valves. This scheme was built by a Joint Venture between ASEA and GE (General Electric). The scheme clearly demonstrated the benefits of HVDC for the transmission of huge amounts of energy over great distances. Nevertheless the records set by the Pacific DC Intertie would be broken many times over the next four decades.

The Manitoba Hydro scheme from the Nelson River area in northern Canada to Winnipeg in central Canada was commissioned in 1971. The first bipole consisted of a 450kV, 1620MW scheme with 895km of overhead line. The main contractor was English Electric which became GEC in 1968. Bipole 2 was added in 1985 using thyristor valves with converter stations at different locations to Bipole 1.

The last project to incorporate mercury arc valves was a three-converted scheme across London, England. The transmission system consisted entirely of land cable with a total length of 85km between Kingsnorth, Beddington and Willsden operating at 266kV. The system was commissioned in 1972 and shut down in 1987. The main contractor was GEC. This scheme was never upgraded to thyristor valves.

7. RAPID DEVELOPMENT OF HVDC TECHNOLOGY

The first project to incorporate thyristor valves from its inception was the Eel River project in New Brunswick, Canada in 1972. This was a back-to-back scheme operating at 80kV with a capacity of 320MW.

Following the Eel River project a further 75 schemes incorporating thyristor valves and 12 incorporating IGBT valves were commissioned, or were in the process of commissioning, in the 37 years up to 2009 when this paper was written. This work was shared between several companies although ASEA, now called ABB after a merger with BBC in 1987, continues to dominate the worldwide HVDC industry with 60% of the market. The other significant HVDC manufacturers are Siemens and Areva. Tens of thousands of Megawatts of capacity have been constructed and the technology has continued to advance. Whilst it was the introduction of the solid state thyristor valve which ignited the industry the companies involved in the industry have continued to develop technology and there have been many innovations which are beyond the scope of this paper.

The rapid increase in system voltages and capacities has been the driver for meeting greater and greater needs of the electricity supply industry in the late 20th and early 21st century.

The use of IGBT transistors in place of thyristors for some projects has extended the "economic range of HVDC transmission down to just a few tens of Megawatts". This technology is being marketed by ABB as "HVDC Light" with an emphasis on applications such as connection of wind farms to AC grids, undergrounding of power lines in areas where approval for overhead lines cannot be obtained for environmental reasons, provision of electricity to offshore oil and gas platforms and the connection of asynchronous grids.

Three projects from the modern era are described in the following paragraphs to place the more recent development of the HVDC technology in context with the early Mercury Arc Era work. One is the Basslink project between Victoria and Tasmania, Australia, because of its local interest to this audience and because at the time of writing it incorporated the longest undersea power cable in the world, at 298.3km. The second is the Xianjiaba to Shanghai project in China which at 6400MW and +/-800kV is the largest HVDC project undertaken to date. The third is an IGBT project with a modest 50MW capacity, again on the island of Gotland where HVDC was born.

8. BASSLINK HVDC PROJECT

This project forms a 600MW link between Tasmania, with its almost entirely hydro-electric electricity generation system, and Victoria which has vast resources of brown coal and a group of large coal fired power stations in the Latrobe Valley east of Melbourne. There are economic and strategic advantages in linking hydro-electric stations with predominantly "peaking" capability with inherently "base-load" large coal-fired stations.

9. XIANGJIABA TO SHANGHAI

The rapid expansion of industry and urban development in eastern China in recent years has been truly spectacular. This has led to the development of very large hydro-electric projects such as the Xiangjiaba project on the Jinsha River (known in the west as the Yangtse River) about 230km west of the city of Chongping. The city of Shanghai has a population of over 20 million and is heavily industrialised. The demand for electricity is enormous. This transmission link, one of many HVDC schemes built, or being built, in China in the last decade, has a capacity of 6400MW at a voltage of +/-800kV. In this case the transmission system is entirely overhead with a length of 2071km. The system will be commissioned with one pole (half capacity) in 2010 and bipolar in 2011. The equipment is being supplied by ABB and the valves will be of the thyristor type with a rating of 8000 Amps.

10. GOTLAND HVDC LIGHT PROJECT – NÄS TO BÄCKS

This project links a wind farm in the south of the island of Gotland to the grid in the vicinity of Visby. The transmission is at +/-80kV and consists entirely of underground polymer-insulated cable over a route distance of 70km. The capacity of the system is 50MW. The converters are of the IGBT type, using the ABB HVDC Light product, and is an example of the economic application of HVDC to smaller projects, in this case involving quite a long underground cable.

11. THE FUTURE FOR HVDC TECHNOLOGY

In recent times the technology has divided into two distinct streams. Very large very high voltage schemes, some of prodigious capacity are increasingly being used to move large blocks of electricity from power stations to load centres. Most of these projects involve hydro-electric projects with the focus of development in China and India. Voltages, transmission distances and capacities are still rising to meet these demands and there is every reason to believe that this will continue. The prospect of Million Volt transmission links with capacities in excess of 10,000MW over distances in excess of 3000km appear likely in the next decade.

Meanwhile IGBT valve technology is finding economic applications in smaller applications.

In this age of concern for Greenhouse Gas related issues the high efficiency of HVDC is a compelling feature. Historically losses in AC transmission systems have been high but there are now serious attempts to rectify this situation. HVDC will offer a solution in many cases.

12. THE LEGACY OF THE GOTLAND PROJECTS

ASEA, BBC and ABB have maintained their corporate interest in the HVDC market segment for more than 80 years and ABB remains the market leader. The companies have tended to use the island of Gotland as field test facility for each emerging HVDC technological development.

Gotland 1 was the first successful commercial application of mercury arc valve technology and was later extended by using the first thyristor valves in commercial service. Gotland 2 was built later to increase the capacity available on Gotland and Gotland 3 replaced the ageing Gotland 1 scheme in 1987. In 1999 a scheme between Nas and Visby on Gotland was built to connect a wind farm in the south of the island to the grid. This was the prototype for the HVDC Light product and featured IGBT valves and modular construction techniques to reduce costs.

13. THE FATE OF THE MERCURY ARC VALVES

After the introduction of thyristor valves from 1970 onwards ASEA ceased development of mercury arc valves as they were, correctly, confident that the thyristor valves were the way forward and would open the door to higher voltages, higher powers and greater reliability.

Gradually, as the old mercury arc schemes aged, their valves were replaced by thyristors or retired. In some cases there were periods of hybrid operation with converter stations operating with old mercury arc valves and newer thyristor valves in the same converters. In one case, Vancouver Island, the HVDC scheme was replaced by an AC system.

At the time of writing the only mercury arc valves still in service are those in the New Zealand Inter-Island scheme and the Vancouver Island scheme. In both cases these valves are in a standby role, able to be used if necessary but the operators have some reluctance to placing the stresses of operation on the old valves. The mercury arc valves in the New Zealand scheme are scheduled to be replaced by thyristors by 2012-2014.

The remaining mercury arc valves in the Vancouver scheme are still available for service. The operators, British Columbia Transmission Corporation, state that "we are still relying on this system to provide system backup while the new AC system is going through its first few years". Apparently no specific date for retiring these valves has been set at the time of writing. There are 16 valves on each side.

The retirement of these two systems will bring the Mercury Arc Era to an end after more than half a century of successful operations around the globe.

14. SURVIVING HERITAGE OF MERCURY ARC ERA PROJECTS

This rapid rate of change in the HVDC environment has made the preservation of a representative heritage of the Mercury Arc Era technology problematic. Furthermore it can be argued that it is more difficult to demonstrate significant heritage values with a technology whose origin only goes back about half a century.

We face the problem that unless we are careful the engineering heritage of the Mercury Arc Era HVDC will be lost before it is recognised that it has great significance. It would be a tragedy if all the mercury arc valves, which were instrumental in igniting the concept of HVDC, were lost in the race to change them over and replace them by the more recent technology.

Whilst my research has not gathered data from all sources, the current conservation status of the three early projects and the eleven Mercury Arc Era schemes is thought to be as follows:

- At the Mechanicville hydro-electric power station which is still in operation, there are some relics of the Mechanicville HVDC scheme. The room which contained the HVDC equipment still exists but is scheduled for demolition. This room has been used for other purposes since the HVDC equipment was removed but it still contains several wall mounted insulators thought to be connected with the HVDC apparatus. The station also has the drawings of the HVDC equipment and the log books for the HVDC scheme.

- The only known relic of the Elbe Project is a piece of cable in the Deutsches Museum, Munich.

- No conservation of any of the equipment of the Moscow to Kashira scheme is known.

- There has been considerable preservation of equipment from the original Gotland 1 scheme. "On both sides of the Gotland Link, Västervik (mainland) plus Ygne (on the island of Gotland) there is one phase left with old valves, two valves per site. Furthermore there are five panels left with the old controls. There is one anode-porcelain, cut up so all the grids are exposed through the opening. There is also an Ignition and Excitation unit displayed plus a few more bits and pieces". ABB advises that there is a mercury arc testing unit, thought to be of the Gotland 1 era, at the ABB Museum at Ludvika.

- No conservation of any of the equipment of the original Cross Channel scheme is known.

- No conservation of any of the equipment of the original Konti-Skan scheme is known.

- No conservation of any of the equipment of the Volgograd-Donbass scheme is known.

- No conservation of any of the equipment of the Italy/Corsica/Sardinia scheme is known.

- One mercury arc valve from the Sakuma Frequency Converter Station is held by the Tokyo Electric Power Company (TEPCO) Electric Power Historical Museum. Also one mercury arc valve has been preserved at the Sakuma Frequency Converter Station.

- The mercury arc portion of the New Zealand Inter-island scheme is still in reserve service (see paragraph 13 above). There are plans to retain the mercury arc valves, provided that mercury residues can be eliminated. The operator, Transpower, advise that "this may involve a display that features the outer view of a valve but with all contents removed".

- The mercury arc portion of the Vancouver Island scheme is still in reserve service (see paragraph 13 above). Plans for preservation after decommissioning are unclear. There are currently no plans about what to do with the valves once they are retired. The operator, British Columbia Transmission Corporation, have stated "We observed also that most electrical museums typically archived station and generation related equipment. It is a great idea to have HVDC technologies and related history retained in some forms to demonstrate one of the major achievements in electrical power transformation and delivery in the 20th century".

- One 133kV mercury arc valve from the original Pacific DC Intertie and a 100kV mercury arc valve from Gotland are on display in the ground floor lobby area of the Celilo Converter Station in The Dalles, Oregon. The displayed Pacific Intertie valve was taken out of service in 2004. The facility is not open to the general public but tours can be arranged.

- One mercury arc valve and accessories from the original Nelson River scheme has been retained by the owner, Manitoba Hydro. This valve is currently in store whilst the Manitoba Electrical Museum source funds for a suitable building for the valve. This valve is an example of the largest mercury arc valves built for HVDC service.

- No conservation of any of the equipment of the Kingsnorth, London scheme is known.

The preservation of the mercury arc valves from the two schemes to be retired in the near future (New Zealand and Vancouver Island) is of great importance considering the small number of survivors elsewhere amongst the mercury arc valves built for all other schemes. Transpower in New Zealand have indicated that it will not be possible to retain a complete pole, or section of a pole, at either converter station primarily because of space considerations with the development and modernisation of the scheme. It is therefore imperative that the owners of Vancouver Island scheme consider the preservation of the whole converter stations containing the mercury arc valves and not just isolated examples of valves as has occurred elsewhere. The pressure is particularly on British Columbia Transmission Corporation (BCTC), owner of the Vancouver Island scheme as this scheme is not being redeveloped with newer HVDC technology and has in fact already been replaced by an AC system. This provides BCTC with an ideal opportunity to preserve an entire HVDC mercury arc era converter station.

In addition to the provisions listed above by the operators of HVDC schemes there is an initiative in Västerås, Sweden (about 90km west of Stockholm) by a group of retired electrical engineers to create a technical museum to house machinery from various HVDC schemes. The museum will be housed in an old power station. A mercury arc valve from the Gotland 1 scheme has already been acquired and there are plans to acquire a mercury arc valve from the New Zealand Inter-island scheme. It is hoped that this museum will open in 2010.

Conservation of equipment from the Thyristor Era is an issue for the future. All these schemes are still in service except three back-to-back schemes, two in Austria and one in Germany. Experience suggests that little planning for heritage conservation will be made, if it is made at all, until the decommissioning of the equipment is imminent. At this point the concern for the preservation of thyristor technologies is less urgent as there are still many in service. Keeping a watching brief on this situation as the technology becomes older and is superseded is a future challenge.

15. CONCLUSION

HVDC technology has progressed very rapidly since the first commercial project in 1954. Two distinct eras have emerged – the Mercury Arc Era and the Thyristor Era. A very large proportion of the equipment from the Mercury Arc Era has already been destroyed.

Heritage conservation has not been a high priority to the HVDC industry although three museums, in Sweden, Canada and Japan, have Mercury Arc Era valves on display or plan to do so.

Great effort is required by the engineering heritage community to ensure that conservation of the remaining Mercury Arc Era equipment still in reserve service in New Zealand and Canada is achieved.

A future generation of conservation and heritage engineers will have the task of ensuring preservation of HVDC equipment from the Thyristor Era and the related IGBT schemes. Much of this equipment is much larger, currently in service in HVDC schemes of a magnitude which would have been unimaginable to the early engineers working in the field. This represents a great future opportunity but also a challenge as accommodation of such large machinery in museums is always difficult.

16. ACKNOWLEDGEMENTS

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Early Electricity Supply in Melbourne

Miles Pierce B E (Elec), F I E Aust.

SUMMARY: *This paper traces the commencement of public electricity supply in Melbourne in 1882, placing it in the vanguard of similar developments worldwide. The subsequent participation of other private enterprise ventures and the entry of the Melbourne City Council into the field are then outlined along with the range of electricity supply technologies that were successively adopted, from HV series DC, single-phase AC, low-voltage DC to 3-phase AC.*

1. BACKGROUND

The practical application of electricity commenced in 1800 with Alessandro Volta's 'voltaic pile', a form of primary battery that enabled the supply of a sustained electrical current. In 1808, Sir Humphrey Davy demonstrated the electric arc light source between two carbon rods connected to a large battery.

The pivotal experiments by Michael Faraday during the 1830s in discovering electro-magnetic induction paved the way for the development of the electric generator and electric motor wherein mechanical energy could be converted into electrical energy and vice-versa. In 1858, Frederick Holmes' permanent magnet magneto-electric machine was successively utilized to power an arc lamp in a UK lighthouse. This was followed in 1867 by Wilhelm Siemens' patented self-excited, continuous-current generator with electromagnetic poles, which he called a 'dynamo'. In 1870, the Belgian, Theophile Gramme produced his ring wound armature, direct current generator with its multi-segment commutator, a machine which operated equally well as an electric motor. Gramme also developed an early AC generator (alternator). These early electro-mechanical machines were rapidly improved upon by other electrical workers in the UK, in Europe and in the USA (Dunsheath 1962; Hughes 1983).

By the beginning of the last quarter of the nineteenth century the means was thus available to generate electricity from mechanical prime movers, most notably the steam engine, and to provide powerful electric lighting by means of the electric arc lamp. The arc light was however not suited for office or domestic lighting applications. The problem of 'subdividing the light' of the arc lamp was solved at the beginning 1879 by the Englishman Joseph Swan's invention of an incandescent electric lamp. Thomas Edison working independently in the USA arrived at a similar solution and patented his incandescent lamp late in the same year (Dunsheath 1962).

In 1885 Ganz & Co. of Hungary successfully developed and marketed a high-voltage alternating current system that used parallel connected transformers stepping down to low-voltage – typically 100V – for end-use applications such as incandescent lighting in commercial and domestic premises. This pioneered the way for the generation and transmission at high AC voltages that overcame the distance constraint on DC electricity supply schemes. The AC system was taken-up in America by the Westinghouse Electric Co. in opposition to Edison's DC supply systems (Hughes 1983).

Early electricity generation for lighting purposes utilized both continuous-current or DC generators (dynamos) and alternating current (single-phase) generators (alternators). The respective systems were vigorously promoted by their protagonists in what became known in the late 1880s as 'the battle of the systems' (Hughes, 1983). Those advocating DC pointed to the ability to utilize storage batteries in conjunction with DC generators and the ready availability of DC motors, whilst the AC system exponents lauded the benefits of high-voltage transmission with transformers being used to furnish low-voltage close to the end-use locations.

2. EARLY ELECTRIC LIGHTING VENTURES IN MELBOURNE

In 1863, three arc lamps powered by primary batteries were erected outside of Parliament House, the Post Office and the Telegraph Office to celebrate the marriage of the Prince of Wales (later King Edward VII). Much interest was aroused at the time but the installations were expensive to run and were thus short lived (Australasian Ironmonger 1890; Bate 1934).

During the 1870s a number of individual companies, including Sands & McDougal and (ironically) the Apollo Candle Co. set up in-house arc lighting installations using gas engine driven dynamos (50V systems). In 1879, a night football match was staged at the Melbourne Cricket Ground using arc lights on temporary tower structures with dynamos driven by portable engines. Reportedly it was not a great success and after one further try it was discontinued.

In September 1880, Melbourne watchmaker, Mr R E Joseph founded the Victorian Electric Company (VEC). Joseph had developed a keen interest in the practical applications of electricity and the business opportunities that it offered. The initial capital of the company was modest, however its stated objectives were: ‘to produce and sell electric machines for electric lighting, motive power, &c, and to supply for hire, and maintain, electric light for public and private purposes’ (Australasian Ironmonger 1890). During the following year Joseph demonstrated an arc light outside his premises in Swanston Street, Figure 1, which heightened local interest in the new electric lighting (Slater 1982).

Figure 1 *Arc light demonstration Swanston Street*

In the same year, the VEC obtained a Melbourne City Council (MCC) contract to light the Eastern Market. The installation comprised six arc lights powered by portable engine driven dynamos. This was successful, and the contract was successively renewed through to 1894. The original company was re-floated in late 1881 as the Australian Electric Company Limited (AEC) with increased capital and with W C Kernot (later professor Kernot) as its chairman. The new company purchased land and erected a two-storey brick building in Russell Place, off Bourke Street, for a workshop and the nucleus of a central generating station.

A publication on ‘Electric Lighting’, authored by Joseph in 1881 as ‘Electrical Engineer to the Australian Electric Company’, promoted the advantages of electric light and set out information on the generation, transmission and utilization of electricity for lighting and other purposes (Joseph 1881).

3. THE BEGINNING OF PUBLIC ELECTRICITY SUPPLY IN MELBOURNE

In the latter part of 1882 the Australian Electric Company (AEC) commissioned a small central generating plant in the ground floor of its Russell Place building to supply street lighting in adjacent parts of Swanston and Bourke Streets and lighting in some nearby private premises. The initial system comprised two Marshall steam engines of about 100hp (75kW) each driving through counter shafts a series of small 50volt dynamos and a single 100V alternator (Curtis 1930). The company also manufactured dynamos, arc lights and other electrical equipment on the upper floor of its building.

AEC’s central generating plant and associated public electricity supply commenced operation in the second half of 1882, and was contemporary with Edison’s first public electricity supply scheme in London at Holborn Viaduct, which was commissioned in April 1882, and the famous Pearl Street central public supply power station in New York which started in September 1882. AEC’s enterprise was also inaugurated within a year of the public electricity supply for the small town of Godalming in Surrey (UK), which is widely considered to have been the first public electricity supply in the world (Parsons 1939; Haveron 1981).

At the end of 1882, the AEC demonstrated for the first time in Melbourne the then new incandescent electric lamps in the Atheneum Theatre with supply from their Russell Place generating plant. This was followed by an extensive installation of incandescent lights, plus some arc lights, in the also nearby Opera House, later known as the Tivoli Theatre (Australasian Ironmonger 1890; Slater 1982). In 1883, the Victoria Coffee Palace, later known as the Victoria Hotel, installed electric lighting in public rooms, and became another of AEC’s early customers.

In 1883 the AEC faced it first competition from the Australian Electric Light & Storage Co. who won a one-year contract from MCC to light Elizabeth St. The contract was however not renewed and the AELSC subsequently disappeared from the Melbourne scene, although they were involved in enterprises elsewhere in Australasia and influenced later electricity industry developments in Melbourne (Salter 1982).

Due to the low initial operating voltage, the AEC was not able to supply customers who were more distant from its Russell Place premises and instead set up company owned generating plant in the customer’s premises. These separate installations included the State Library, the Princess Theatre and Parliament House. By 1887 however, the company had installed three 2000V Ganz alternator sets driven by high-speed steam engines at Russell Place with distribution then being at 2kV AC and with 2000/100V Ganz step-down transformers at or close to end-use supply points. This then enabled the former local generating plants to be retired (Curtis 1930).

Around 1886, A U Alcock set up a small generating plant in Alcock’s timber yard off Corr’s Lane and in 1888 gained permission from the MCC ‘to erect 5 masts in the centre of Russell Street, between Bourke Street and Lonsdale Street, and to lay underground wires for street lighting and for lighting premises’ (Ruddock c1982). His plant comprised three steam engines driving four arc lighting dynamos and a small alternator (Curtis 1930). About the same time, Alcock also established another small public supply generating station in South Melbourne (Bate 1934).

For the Melbourne Centennial International Exhibition in 1888, a large electric lighting system was designed and implemented by K L Murray who was seconded from the Victorian Railways. This installation comprised 1000 arc lights, 40 'Sunbeam' 400cp lamps and 3000 6cp incandescent lamps. It was supplied from multiple dynamos driven through counter-shafting by Austral Otis slow-speed steam engines housed in a large annex adjoining the Exhibition Building (Murray 1899).

In 1889, the Union Electric Company (UEC) who had established a small generating plant in Heffernan Lane was contracted by the MCC to erect 15 arc lights at city street intersections. This Council contract was reportedly predicated by a general strike effecting gas supply.

Despite its earlier success, by the late 1880s the Australian Electric Company was seriously under capitalized and struggling to survive. It was formally wound up at the end of 1888. The remaining assets passed to a new company called the New Australian Electric Company (NAEC) early in 1889 (Slater 1982). This company, with substantive new financial backing, promptly embarked on the construction of the first part of a new central station at Green Street in suburban Richmond. It commenced operation in the following year.

The initial plant at Green Street in Richmond, comprised three, 2kV Elwell Parker, single-phase alternators (97cps) driven by 200hp (150kW) cross-compound Robey steam engines together with four arc lighting dynamos, Figure 2, (Curtis 1930). AC distribution for public and private electric lighting from this station was by mainly overhead lines, with 2000/100V transformers for individual low-voltage services. The station also contained four constant-current, 3kV, arc lighter dynamos driven via counter shafting from a fourth steam engine. The latter plant was similar to the City Council's c1894 plant at Spencer Street – see below – and probably supplied series connected streetlights in nearby parts of Richmond and South Yarra. The NAEC distribution area included southern parts of Richmond, and across the River to South Yarra and Prahran, as well as back into the central business district (CBD).

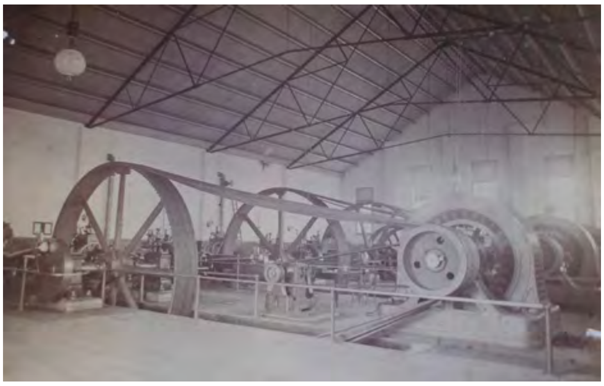

Figure 2 *NAEC Richmond Generating Plant*
Avery Collection Melbourne University Archives

In the next year – 1891 – A U Alcock, as the Electric Light & Motive Power Company (ELMPC), opened the initial part of a planned large central generating station in Burnley Street, Richmond. It comprised four steam engine driven 80kW, 2kV Ganz single-phase alternators, similar to the NAEC plant at Green St. Like the latter, electricity was distributed at 2kV for street lighting and private customers in north Richmond, Abbotsford and Collingwood as well as some parts of the Melbourne CBD, however the AC frequency of 42Hz was different (Building & Engineering Journal 1891). The two companies were in active competition, particularly for CBD customers.

As well as differences in the frequency, the voltage waveform of the early alternators was typically not a simple sine wave. The resulting harmonics would have caused additional losses in the early transformers that were themselves fairly basic devices. Differing voltage waveforms between machines also complicated the successful parallel operation of alternators (Dunsheath 1962).

4. ENTRY OF THE MELBOURNE CITY COUNCIL

The Melbourne CBD streets had been lit by gaslight from 1857. From the outset however, relations between the MCC and the gas company over cost and performance were strained and at times quite antagonistic, aided by a critical press (Slater 1982; Proudley 1987). With the successful deployment of alternative electric arc lighting in parts of some city streets by the private electricity supply companies in the 1880s, the Council, spurred on by its strong minded Town Clerk who had a particular disdain for the gas industry, began to consider entering the electric lighting field in its own right.

In 1891 the Melbourne City Council (MCC) formally resolved to establish its own power station and distribution for electric street lighting in the CBD (Ruddock c1982). Mr A J Arnot from the Union Electric Company was appointed as the first City Electrical Engineer with responsibility for the day-to-day running of the Melbourne City Council Electricity Supply Department (MCCESD).

The MCC's Spencer St. power station (SSPS) was commissioned in March 1894 with the first of four locally built Austral Otis 300hp (225kW) slow-speed steam engines each driving up to five Thomson Houston constant-current 3kV arc lighting dynamos via counter shafting. A rope drive was used between the engine flywheel and its section of the countershaft with the individual dynamos then driven from the latter with flat belting via fast and loose pulleys. Figure 3 shows the original engine room. This was similar to the plant arrangement used for the 1888 Centennial Exhibition lighting (see above), and required a large engine house. Each engine was supplied with steam from a Babcock &

Wilcox water tube boiler in an adjoining boilerhouse. Only three of the four sets of plant were required to carry the full lighting load so as to maintain supply security in the event of a failure of any one item. The dynamos were connected individually - via a plug-and-socket panel - to supply a single series-connected lighting circuit comprising arc lamps for the main streets, plus special incandescent lamps for the minor streets and lanes (Arnot 1894).

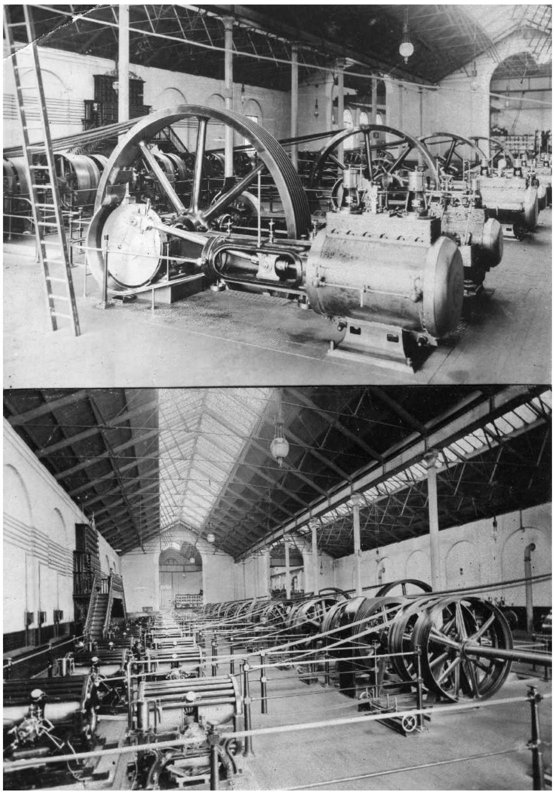

Figure 3 *Spencer St. P S Arc Lighting Plant 1895*

The constant-current series connected system was at that time commonly used for municipal street lighting in the USA and in some places in Great Britain (Arnot 1894) and had the advantage of requiring only a single, small cross-section conductor. However, due to the installed dynamos having only a small number of commutator segments, the current - although unidirectional - had high-frequency variation, resulting in interference to telephone circuits in the vicinity of the single-wire overhead power lines (Ruddock c1982).

The electric street lighting rapidly replaced the old gaslights and was generally considered to provide a much better illumination, although the deep shadows away from the brightly lit areas close to each arc light were sometimes criticised. In all, some 650 arc lamps and 1200 incandescent lamps were installed by the mid 1890s to light the Melbourne CBD streets and laneways (MCCESD 1915).

Four 75kw, 2kV, single-phase alternators were added in 1895 - using the spare positions on the counter shafts – for overhead distribution for street lighting and private premises supply in Council areas outside the CBD. 2000/100V transformers were installed on poles or at customer premises. The frequency of the MCCESD AC system was 72Hz, different again from both the NAEC and ELMPC AC systems, but in the early days of electric lighting AC frequency was considered of little import and it was not referred to in the specification (Ruddock c1982). The generating plant at Spencer Street power station, as described above, was similar to what was installed at Launceston's Duck Reach hydroelectric power station under K L Murray which was commissioned in December 1895, albeit that in the latter case the dynamos and alternators were individually direct-coupled to water turbines, and the AC frequency was 92Hz (Pierce 2007).

The year 1895 saw the passing of the first Victoria Electric Light & Power Act. Inter alia, the Act provided that:

- An Order-in-Council (O-I-C) was required to distribute electricity.
- Existing Council or company electricity supply undertakings were automatically entitled to obtain an O-I-C and Councils similarly entitled in respect to their respective municipal areas.
- Local Councils were able to take out non time limited O-I-Cs for their areas and able to contract out construction and/or operation to other parties.
- Non local government bodies were only able to obtain O-I-Cs for public supply with the consent of the relevant local Council(s) for a period of 25 years and the Council(s) able to compulsorily acquire the assets after expiry of 30 years.
- Electricity distribution was expected to be underground unless specific consent was obtained for overhead distribution.

Order No.1 was granted to Alcock's Electric Light & Motive Power Company, and Order No. 2 to the New Australian Electric Company.

In 1899 the MCC resolved to become the sole electricity supply undertaker in its municipal areas for which it had obtained O-I-C No. 3 in September 1897. Council thoughts of taking over the NAEC and the ELMPC enterprises lapsed without the support of other Councils served by them and arrangements were eventually made to compulsorily purchase only those assets of the two companies within the MCC boundaries. The final transfer was completed in January 1901. The MCC also purchased the Union Electric Co. and its assets in 1899.

Early in the 20th century, other suburban municipal councils took out O-I-Cs for their areas, but although some considered setting up their own generating plant, all ultimately arranged to cede their rights to the MCCESD or the MESC (see later re the latter entity) or in ten cases, to purchase electricity in bulk from one or other of these undertakings and then arrange their own electricity distribution and retailing.

5. THE INTRODUCTION OF DC SUPPLY

As a result of 'many applications' being received by the MCC for supply of electricity for motive power purposes, the opportunity to do so was actively pursued by the Council (Ruddock c1982). A potential advantage was better generating plant utilization by increasing the daytime load. The idea was however strenuously opposed by the Melbourne Hydraulic Power Company who from 1889 had operated a public hydraulic power utility service in the CBD and some adjacent areas and who considered that they had a monopoly for supplying motive power, especially for lifts (Pierce 2008). After some resultant delay, the Council elected to proceed. Mr Arnot visited England and America to investigate latest practice. A decision was subsequently made to retain the 2000/100V single-phase AC for areas outside of the CBD and to develop an entirely new low-voltage 3-wire DC system for the CBD using underground cables (Ruddock 1982). The merits of the DC system were cited as:

- Direct supply from generators avoids transformers and their losses
- All classes of motors for elevators and other motive power can be economically and successfully operated
- Accumulators can be used for storage and back-up for light day load
- No interference with telephone circuits by induction – no AC
- As the maximum pressure is 450 volts, no danger to life if contact is made at any point.

The last point is interesting – they must have been tougher in those days!

In 1900 the MCCESD commenced construction of a DC system for the CBD. The new DC plant at Spencer Street PS comprised four 350kW, 460V DC generators driven by Belliss reciprocating steam engines, as depicted in Figure 4, supplied from four Babcock & Wilcox water tube boilers, plus a 300Ah Tudor accumulator. A three-wire, 460/230V supply was provided using conventional motor-generator balancer sets. Underground cable mains were run to cast-iron curbside pillar-boxes from whence fused outgoing circuits supplied consumer premises. The old AC series arc lamps for CBD street lighting were progressively converted to DC flame-arc lamps. A new 120kW steam engine driven single-phase 2000V alternator was also added to augment the four original (1895) alternators that were later to be driven by DC motors from the 460V DC system. The new plant was accommodated in an eastward extension of the original c1893 engine room and a new boiler house and chimney were also added (Ruddock c1982).

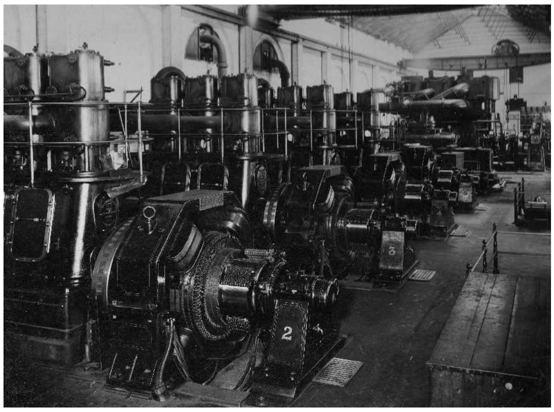

Figure 4 *Spencer St. P S 350kW DC sets c1901*

To encourage the use of electricity for motive power purposes and thus obtain better utilization of generating plant during daylight hours, the Council moved to introduce a separate light and power tariff with the former being charged at 5d/kWh (≈$2 today) and the latter at 3d/kWh (≈$1.25 today). The legality of this intention was vigorously challenged by the Gas Company on the grounds that it discriminated between customers and was contrary to the Act. After multiple court actions and appeals, a special amending Act was passed giving both the Council and the Gas Co. the right to have two-part tariffs. 'An unarmed truce was restored between the parties' (Ruddock c1982).

Whilst the changeover to the new DC system proceeded, the Council continued to operate the generating plant of the former private undertakers at Russell Place and Heffernan Lane as well its own generating plant at the Spencer Street power station. Electricity was also purchased for some time from the NAEC's Richmond power station.

6. SUBURBAN GENERATING COMPANIES

With the sale of the electricity supply assets in the City of Melbourne area to the Council, the Brush Company (UK) was able, in 1901, to complete its planned amalgamation of the former NAEC and ELMPC into a new UK registered company called the Electric Lighting & Traction Company (ELTC). The decision of the two former companies to accept the Brush proposal was reportedly influenced by difficult financial conditions for both companies following the loss of lucrative customers in the City of Melbourne. The protracted negotiations leading to this outcome are detailed in Lincolne, c1956.

The electrical generating plant for the new combined company was subsequently consolidated at the Green Street power station. The ELTC promptly set about a major system reconstruction, with two new 500kW, 4000/4400V, 50cps (50Hz), single-phase alternators and tandem-compound engines plus new Babcock & Wilcox water-tube boilers being ordered and installed. The distribution was then progressively converted to 4.2kV (nominal) single-phase, mainly via underground cables, with local step-down transformer substations supplying 400/200V, 3-wire LV reticulation (Smith 1951; Lincolne c1956).

Bate, 1943, attributes the adoption by the ELTC of 50cps (50Hz) to the influence of the Brush Electric Co. who themselves had by that time standardized on this power frequency.

A 1000kW, 4.2kV, single-phase, vertical shaft, Curtis-BTH turbo-alternator was installed at Green Street power station in 1905, however BTH discovered a design fault that precluded its commissioning. After fitting of some replacement parts the set was operated at times of high load at up to 50% of rating until the alternator was completely replaced by BTH and then the turbine substantially rebuilt, all of which took until the end of 1908. A 1500kW Brush-Parsons single-phase turbo-alternator was also commissioned in the same year, although it too experienced early operating problems (Lincolne c1956).

In 1907, the Electric Light & Traction Company changed its name to the Melbourne Electric Supply Co. (MESC), and supplied an increasing suburban area outside of that under the control of the Melbourne City Council. The MESC 4.2kV single-phase distribution in 1910 extended from Fitzroy in the north, parts of Kew to the east, Brighton in the south and South Melbourne to the west. Transformer substations for local low-voltage supply were typically in underground pits excepting for main feeder centres (Smith 1951).

A further four single-phase, 4.4kV turbo-alternator sets with capacities from 2MW to 6MW were installed at the MESC Green Street power station between 1911 and 1919 with the earlier sets progressively retired. See Appendix A. Also, in 1921-22, two 5MW, 25/50Hz frequency changers were installed to permit importing then spare capacity from the new Victorian Railways Newport Power station (Curtis 1930; Lincolne c1956). The nominal 4.2kV single-phase underground cable distribution to 'main distributing centres' in surrounding suburbs for which the MESC had O-I-Cs, and for bulk supply to municipal electricity undertakings in other eastern areas, continued to be expanded and augmented (Smith 1951).

Separately, in 1906, the North Melbourne Electric Tramway and Lighting Company commissioned a power station in Mount Alexandra Road with an initial capacity of 250kW at 500V DC for supply of an electric tramway. It also provided public electricity supply at 230/460V DC in the nearby Ascot Vale and Essendon suburban area under its own Order-in-Council authority (Lincolne c1956).

7. MCCESD DEVELOPMENTS

In 1907-08 the MCC outer area supply was converted to 4.4kV, 50Hz, single-phase AC with customer supply transformers stepping down to 200V compared with 100V previously. This meant that supplies for lighting in the CBD were at 230V from the DC system, whilst the outer areas had a 200V AC service, as had been adopted by the ELTC for their suburban supply areas. After some temporary interim provisions, two Westinghouse single-phase 750kW turbo-alternators (T/As) were installed in a space made available in the SSPS engine room by the removal of original 1894 arc lighting dynamo plant. The DC generating capacity was also progressively increased with 3 – 750kW generators driven by Allen triple-expansion engines together with increased boiler capacity. Figure 5 shows the engine room at this time.

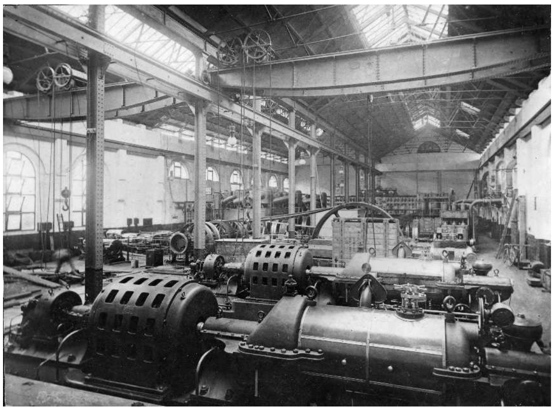

***Figure 5** SSPS Engine Room c1908 showing T/As*

In 1911 a 1500kW DC generator also driven by an Allen triple-expansion steam engine was installed at the MCC's Spencer Street power station and a 4000Ah accumulator installed at the Heffernan Lane site to further augment the CBD DC supply capacity. Voltage-drop on long DC cables was however becoming a major problem. Following a visit to Europe and UK by Mr H R Harper (then the City Electrical Engineer), a major decision was made to changeover to 3-phase, 6.6kV generation at Spencer Street PS and to convert to DC by rotary converter substations closer to the main load centres (Ruddock c1982). The development of the rotary converter in the USA around 1890 made this configuration convenient and it was employed in many other northern hemisphere cities where, like in Melbourne, a DC supply system existed. This expedient was also adopted for DC supply customers in the City of Sydney when the city corporation commenced its public electricity supply scheme in 1904.

Following the installation of a Siemens 4400kW, 6.6kV, 3-phase turbo-alternator at SSPS in 1913, two more 4400kW, 6.6kV, Willans-Robinson turbo-alternators were installed in 1914, in the space vacated by the retirement of the original four 350kW DC engine-generator sets. See Appendix A. A new condenser cooling water system was also constructed in the form of a two-compartment concrete box flume at grade from the

Yarra River to the SSPS under Spencer Street. This replaced the previous pumping station at Spencer Street Bridge and the 600 diameter cast-iron pipeline to SSPS. It is notable that owing to the large floor area requirements of the original c1894 generating plant, the higher capacity new generating plant could be housed in the original engine room and its c1901 extension for the first DC plant.

Four, 1500kW, 460V rotary converters, with associated step-down transformers, were installed at Heffernan Lane substation in 1915 and supplied via 6.6kV, 3-ph underground cable feeders from Spencer Street power station (Ruddock c1982). This was followed by four more rotary converter substations, with the last being commissioned in 1929 at Russell Place on the site of the former AEC's original generating plant. Figure 6 shows a rotary converter at Russell Place substation, c1930.

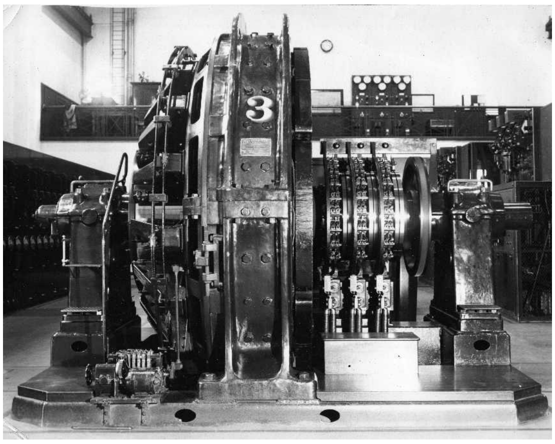

Figure 6 *Rotary Converter Russell Pl. Substation*

Retiring of the former 4400V, single-phase turbo-alternator sets and associated HV distribution in the MCC's outer areas and the conversion to 6.6kV, 3-ph, followed progressively in subsequent years with the low-voltage customer supply then becoming 400/230V, 50Hz – yet another change that was not completed until 1926. This included nearby northern and western municipal areas to which the MCCESD had provided bulk supply from 1912. Remaining parts of the 4400V single-phase system were supplied by auto-transformers from the 6.6kV system in the interim.

In 1921 the MCCESD supply capacity from SSPS was augmented by provision for importing up to 5000kW at 6.6kV from the newly constructed Victorian Railways power station at Newport, similar to the MESC at Richmond. For this supply to the MCCESD, a 25/50 Hz frequency changer was installed at Newport power station (later designated NPS 'A').

1930 was the peak year for the CBD DC supply system with a total of 43.5MW of 460V DC rotary converter capacity installed at five CBD substations and at SSPS. All were supplied in turn from the 6.6kV, 3-phase turbo-alternators at SSPS. A decision was made in 1932 to eventually phase out the DC system in favour of AC. Three-phase 6600/400V AC substations were established in the CBD from 1929 (Ruddock c1982). As the DC demand subsequently declined, the rotary converter plant was progressively reduced and by 1953 the Heffernan Lane substation was the sole DC substation with three 2500kW rotary converters supplying the DC distribution cable network. Two years later, the first of three glass bulb mercury arc rectifier assemblies were installed, initially to permit de-manning at night and weekends and later, as the DC load further reduced, totally replacing the rotary converters by 1957 (Ruddock c1982).

Implementation of the 1932 decision to phase out DC supply in the CBD was however not fully completed until 2003 when the last 460/230V DC customer supply – to the Victoria Hotel for a DC lift – was terminated. From about 1980, the progressively diminishing number of DC customers were supplied from mercury arc rectifier plant that had been relocated in 1962 from Heffernan Lane to the Russell Place substation, on the site of the original c1881 AEC premises. The DC equipment at 'RP' substation was still extant at the time of writing.

8. THE STATE ELECTRICITY COMMISSION

The Victorian Government passed the Electricity Commissioners ACT in 1918 and three part-time commissioners were appointed. Mr Harper, the former MCC City Electrical Engineer resigned from the MCCESD to take up the position of Chief Engineer.

In 1921 the State Electricity Commission of Victoria (SECV) was established under the chairmanship of Sir John Monash. The initial project was to develop Victoria's LaTrobe Valley brown coal deposits for bulk generation of electricity for the state. The first brown coal fired power station to come online was located at Newport adjacent to the Victorian Railways Newport 'A' traction supply power station. Denoted as Newport 'B' (2 x 15MW), it was commissioned in 1923, one year ahead of the first LaTrobe Valley power station, Yallourn 'A' (SECV 1949; Edwards 1969).

By 1923, a 22kV connection was made from the SECV's Newport 'B' power station to a substation on the MCCESD Spencer Street site (later denoted as substation 'J') with 22/6.6kV transformers to interface to the MCCESD's AC system. This enabled up to 10MW importation and superseded the earlier 6.6kV connection from the Victorian Railway's Newport 'A' 25Hz power station. Other provisions for bulk importation from the SECV system were made in later years (Ruddock c1982).

1925 saw the first stage of conversion to 3-phase importation from the SECV for the MESC supply areas with 6.6kV, 3-phase distribution in Fitzroy and Collingwood. In 1927, the single-phase 4.4kV generating plant at Richmond was scrapped and replaced in 1929 by an SECV, 15MW, 3-phase, 6.6kV turbo-alternator (Curtis 1930; Smith 1951). The still extensive 4.2kV single-phase distribution was supplied by transformers from the SECV network pending its eventual conversion to 3-phase and 400/230V low-voltage services.

In 1930, the Melbourne Electric Supply Company (MESC) was formally acquired by the SECV after having been effectively administered by the Commission since the expiry of MESC's Order-in-Council authority in 1925.

Although the MCCESD took bulk supply from the new SECV power stations, the capacity of its Spencer Street power station continued to be expanded. Four new 5500kW, 6.6kV turbo-alternator sets were installed between 1927 and 1939. After 1941, the generating units at SSPS were dispatched by the SECV but ownership and operation remained with the Council. (Between 1949 and 1959, two 15MW and two 30MW Parsons turbo-alternators were installed in 'B' and 'C' engine rooms on the Spencer Street site and operated until 1981. Most of the site has recently been demolished).

9. MELBOURNE'S PLACE IN PUBLIC ELECTRICITY SUPPLY DEVELOPMENT

As outlined earlier, Melbourne was very much in the vanguard of public electricity supply implementation. However, as with other emerging technologies, this sometimes retarded the adoption of later developments and/or compounded their eventual cost due to the need to transition from the earlier technology.

The City of Sydney Corporation was a comparatively late entrant to public electricity supply and when it inaugurated supply from Pyrmont power station in 1904, electricity generation and distribution to city substations was at 6.6kV, 3-phase, 50Hz, from the outset (Wilkenfeld & Spearritt 2004). The MCCESD did not introduce three-phase generation and distribution until 1913 and converting AC supply areas outside of the CBD from single-phase to three-phase distribution, including an increase in the nominal low-voltage level, took until 1926 to complete (Ruddock c1982). In the case of the MESC, single-phase generation and distribution was retained until 1925 and then the conversion to 3-phase distribution - under the auspices of the SECV - of the many suburbs supplied out of Richmond took until the late 1950s to complete (Smith 1951). By contrast - albeit for a smaller distribution area - the Launceston scheme which commenced in 1895 with HV DC series arc lighting for the CBD and 2000V single-phase AC for other areas, based on generating plant at its Duck Reach hydroelectric power station, converted to 3-phase AC supply and distribution by1905 (Pierce 2007).

Low-voltage DC distribution, as implemented in Melbourne at the beginning of the twentieth century, was similarly adopted by other public electricity supply enterprises elsewhere in the world where the competing claims of the two systems won out in favour of DC rather than AC. For supplies in smaller towns where feeder distances were typically short, DC distribution remained viable until local generation was supplanted by eventual connection to regional electricity transmission networks ('grid supply').

10. CONCLUDING COMMENTS

Melbourne was one of the first major cities in the world, along with London and New York, to have a public electricity supply whereby electricity was distributed from a central generating station to paying private customers and was also used for public street lighting, replacing gaslights. As elsewhere, the pioneering electricity supply enterprises were privately financed and in Melbourne's case were initially quite small. The nascent electricity supply enterprises were adventurous in rapidly taking up and adapting a new public utility technology that had its origins in the UK, USA and Europe but which enabled local ingenuity and entrepreneurial spirit to flourish.

The entry of the Melbourne City Council into the public electricity supply arena from the mid 1890s and the subsequent establishment of other suburban municipal electricity supply undertakings, assisted by provisions of the 1895 Victoria Electric Light & Power Act, was a significant commitment by Local Government to an evolving technology. Until the takeover of the Melbourne Electric Supply Company (MESC) by the State Electricity Commission of Victoria, private enterprise also continued to play an important role in advancing the availability of electricity supply to commercial, industrial and residential consumers in Melbourne.

Following a total restructuring of Victoria's electricity supply industry in the mid 1990s, 'the wheel has turned full circle' with the generation, transmission, distribution and retailing functions again in the hands of private sector entities.

In conclusion, it is contended that as well as being a front-runner, Melbourne's early public electricity supply development encompassed most of the evolutionary technical and structural facets of the industry.

11. ACKNOWLEDGEMENTS

The photographs reproduced in Figures 3 to 6 are from T Ingram's prints collection.

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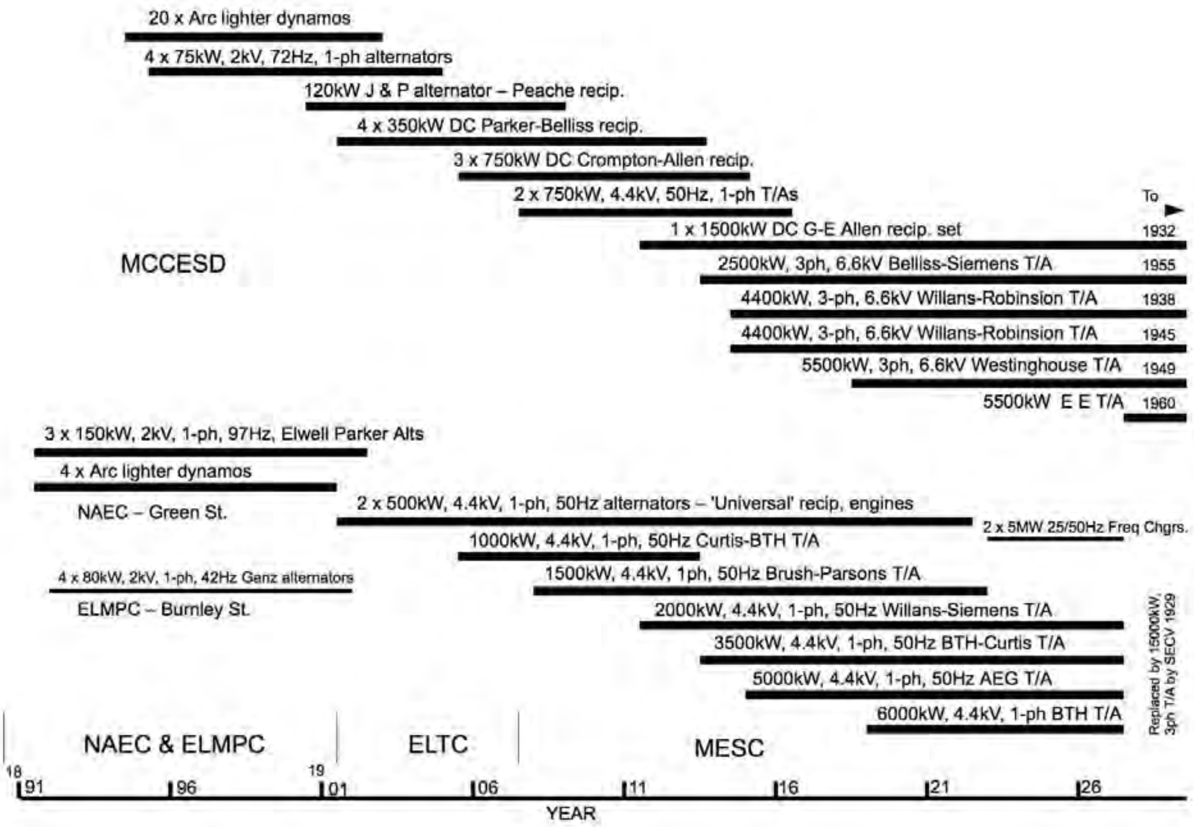
Appendix A. Melbourne Public Electricity Supply – Generating Plant 1890 to 1930*



* Excludes SECV (1923 -)

Preservation by Operation:
Experience of the Restoration and Operation of Large Stationary Steam Engines and the Implications for the Professional Engineer.

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SUMMARY: *Restoring a superseded large stationary steam engine to an operational condition for educational and entertainment reasons is an attractive proposition to many, including professional engineers. Yet there are many problems in adapting such machines to work under off-design conditions in the context of a voluntary group in the culture of 21st century safety and responsibility. This paper discusses the experience gained over thirty five years at three such museums in London. In particular, the need for careful appraisal of how the engine will behave in its new role, the requirement to carry out the work within conservation guidelines, and the problems of maintaining and operating the engine after restoration is complete are reviewed.*

KEYWORDS: *steam engines conservation restoration risks*

1. BACKGROUND

Over the last 40 years many stationary steam engines have been the target of restoration projects. The sight of a stopped engine excites something irrational, even maternal, in the minds of engineer and non-engineer alike. Let's get it working again!

Today I want to consider this phenomenon, what it has achieved and, in particular, the rewards and hazards of being involved from the point of view of the professional engineer, that is, somebody with chartered status who, perhaps, should know better.

The views expressed in this paper are entirely my own and I am only talking about enthusiast run sites.

There are quite a few such sites in the UK running large stationary engines for pleasure. Most are water pumps, some are mill engines, a few are steam winders. Altogether 25 of them are demonstrated in steam on a regular basis.

At Kew Bridge Steam Museum there are five non-rotative Cornish cycle engines still in their working positions, with cylinders 64, 65, 70, 90 and 100 inches in diameter. Four have beams to connect the steam piston to the pump ram, the other is a “Direct-acting” or “Bull” type engine with the piston and pump ram on a common rod. There are also four large rotative water pumps brought in from other sites.

As long ago as 1932, the Metropolitan Water Board (MWB) discussed preserving the Bull engines at Hampton. It didn't happen, but the seed was sown. It is not surprising that the nest of Cornish engines at the Kew Bridge Works was earmarked for preservation when the steam pumping plant was replaced during World War II by centrifugal pumps and electric motors.

Figure 1. *Cornish engines at Kew Bridge, London*

The senior engineers behind this had no intention of allowing the Cornish non-rotative engines to be run again but the restoration team that arrived at Kew Bridge in 1974 had other ideas and brought the 64 inch (1600mm) engine of 1820 by Boulton & Watt back to life in 1975, followed by the 90 inch (2300mm) cylinder diameter engine of 1846 only nine months later. This team had cut their teeth restoring the 1812 and 1845 Cornish cycle beam engines at Crofton on the Kennet and Avon canal. These two are low-lift pumps which still perform the same task today. In July this year the replacement electric plant completely failed and for three days the early 19th century steam pumps fulfilled their original purpose, not only filling the head reach of the canal but the coffers of the engine trust as well!

Figure 2. *Engine at Crofton*

Thames Water (TW), as successors to the MWB, were landed with a problem when their pumping station at Kempton Park was designated as a National Monument and they were required to keep and maintain the building and its contents. This plant was in service till 1980, having been commissioned in 1929. It contains the two largest triple expansion engines ever built in the UK plus two turbine-driven centrifugal units. The engines are 62 feet (18.9m) high and are fully visible when entering the building. The impact of their size is unforgettable. Each engine weighs about 800 tonnes and is probably the most sophisticated reciprocating steam engine ever built, certainly in the UK.

Figure 3. *Kempton Park engine*

TW decided that operation was the best way forward, agreed to provide steam and encouraged the formation of a new team of volunteers under the leadership of a very small group who had learned something from previous experience at Kew Bridge and Crofton. Their expertise was focussed on finance, fund-raising, legal agreements, insurance and the like. The technicalities of the engines appeared to be straightforward and there was no shortage of people wanting to be involved in that aspect. Discussions began in 1993 and one engine made its first revolutions under steam in its new incarnation in 2003.

All the restoration projects described have been a success, in that all the engines appear to the layman to be pumping as they always did. But each project has become more difficult, the constraining factors more demanding and the end result perhaps less overwhelming than before. Has the end of the road been reached?

There is one engine at Kew Bridge that has not yet been touched. It is the 100 inch engine; that is, the cylinder diameter is 100 inches, easily converted to 2540 millimetres though the accuracy to the last 10 millimetres must be doubtful. The stroke is around 11 feet (3.35 metres). It was last in steam in about 1957.

Figure 4. *Kew Bridge 100" engine*

There was a formal debate at the museum in June 2009 to bring out all the reasons for restoring, or not, the 100 inch engine. It was most illuminating that the enthusiasm of the "let's do it now faction", about half the audience, had waned considerably by the time they had considered the whole question objectively. Only six people still wanted to go ahead soon, 27 now wanted to preserve the engine as it was, but not to do any of the irreversible work that would be necessary to get the engine moving again.

This more down-to-earth approach stems from many factors which can be included under several headings

1. **Conservation**: The engine must be modified if it is to be steamed.
2. **Design standards**: Is the machine safe by current standards?
3. **Adapting the Design**: Operating conditions will be very different from those of the original design.
4. **Operation and maintenance**: Will well-meaning amateur enthusiasts cope safely?
5. **Risks and responsibility**: Who will take the blame when the accident occurs?

So why are we trying to run these engines? Have we a real purpose? Or are we just having a bit of fun with our big toys? If it is the latter, should we be doing it? Are the risks, the costs and the effort (usually unpaid) justified? Before engineers rush to start work, some of these points are worth thinking about.

2. CONSERVATION

Few would disagree that the best way to conserve large steam engines is to get them back into working order and run them.

With the exception of the canal feeders, these engines can only be run if they are modified – principally to reduce fuel consumption to a manageable cost and to avoid problems with disposal of the output. They must have any asbestos removed (encapsulating the material is not really an option in a public venue), they must use modern packing and jointing materials and they must be fenced off. The result is no longer an authentic experience of the conditions that the engines were used in.

Guidance is readily available on how to approach the conservation of a machine and what should or, more importantly, should not be done when designing the adaptation necessary for safe operation in a museum mode. If funding is to be obtained from State sources, or even from private philanthropic bodies, a knowledge of the principles is important. It is only too easy for an application to be rejected because of some transgression, probably brought about by over enthusiasm to do a thorough job. Based on my fairly extensive contacts amongst those responsible for restoring and operating steam plant, I fear that few are as aware as they need to be of the background and structure of "the business".

At international level there is "The International Committee for the Conservation of the Industrial Heritage", generally known as TICCIH. At their meeting in Russia in July 2003, the delegates agreed on the Nizhny Nagil Charter of the Industrial Heritage. Although this is at very high level, with connections to UNESCO, national and local bodies will take their tone from this international body.

Under "Maintenance and Conservation" the Charter states that "all interventions should be reversible and have a minimal impact. Any unavoidable changes should be documented and significant elements that are removed should be recorded and stored safely".

Most of the restorations at Kew Bridge predate this Charter and there is very little record of what was done. A significant amount of the work was irreversible. Here is the cast iron steam supply pipe for Kew Bridge's Bull engine which had to be replaced in steel to meet modern insurance requirements. The discarded pipe is neither protected nor interpreted.

Figure 5. *Kew Bridge steam pipe*

Operating elderly machines also runs the risk of considerable damage. In the UK we have an engine of the Newcomen type, built in 1795 and still in its original engine house though much of the engine itself is not original. It is a very significant engine and was at work till 1923 when it was preserved by the mine owner. In due course it became the property of the National Coal Board who arranged to steam it, reputedly for a visit of the Newcomen Society, in 1953. It was mishandled and suffered a severe over-stroke which damaged the base of the cylinder. No attempt has been made to repair it and it is now in the hands of the local authority, seldom available for viewing and showing signs of neglect.

Restoring a steam engine to a working condition involves a clear understanding of the constraints and risks if a satisfactory compromise is to be reached.

Although not a museum engine, Figure 6 gives some idea of the forces involved when a Cornish non-rotative engine gets out of hand.

Figure 6*. Smashed spring beam*

3. DESIGN STANDARDS

Kew's 19th century Cornish engines are made of cast and wrought iron, with some parts of brass or bronze. By 1820, Boulton and Watt had a long track record of making such engines with 40 years of experience to draw on. But the use of cast iron for the beam was less than 20 years old, forced on them by the cost of timber.

The two halves of the beam look right, but what design calculations were used? Were they just laid out on the foundry floor by the Head Moulder according to his eye and instinct? I can find very little evidence of real stress analysis or component testing in the 19th century. The evidence given to the enquiries into the Hartley Colliery disaster in 1863 (204 dead) and the Tay Bridge in 1879 (75 dead) are remarkable for their lack of information on how the failed cast iron components were designed and then tested both during and after manufacture. Coincidentally, there were failures of cast iron beams at Kew Bridge in both 1863 and 1879.

Figure 7. *Maudslay beam*

Until 1879 the only beam failures were due to overstroking and impact. One beam half fractured on the now scrapped eastern 1820 Boulton and Watt engine and was replaced in 1863. From photographs it appears to have been a like-for-like replacement. This was not the policy adopted in 1888 when a similar accident befell the 1838 Maudslay engine. This time the replacement half beam was twice as thick as the original. So somebody must have had doubts about the strength of the beams though the accidental cause of these breakages was clear.

When a half beam on the100 inch engine failed in 1879 after only seven years service there was no apparent cause. The crack started in the top flange, close to the centre of the beam, developed through the web and had reached the lower flange when it was spotted and the engine stopped, fortunately without any serious consequences.

The repair consisted of holding the cracked parts in position by a light doubling plate and enclosing each half beam in a system of wrought iron bars with a bridle. The bars were tensioned to put the cast iron into compression by flogging up cotter bars in the joints. One of the fire welds on the wrought iron bars failed three years after installation and this too was repaired. The engine ran like that for a further 63 years under full load.

Figure 8. *Crack in 100" beam*

Now the debate is whether this engine should be restored simply for the education and entertainment of visitors, and for the gratification of those who will undertake the work. The engine had been tested under load for 63 years, and this load will be substantially reduced for museum operation. "What's the problem?" is the normal reaction. Technically, there isn't one, yet I personally feel uneasy about putting this beam back into service, even in museum conditions. How do we know the crack is arrested? Are there any other cracks or stress raisers in the beam? Is the wrought iron trussing effective? The evidence of the strain gauge test on the 90" engine's beam is that the wrought iron system has long since relaxed and is not applying any compression forces.

These questions can be tackled but at what cost, both in cash and in damage to an historic artefact? The fact that the engine ran for 63 years in this condition is history itself. The suggestion, which has been made seriously, that it be welded, or a metalock repair applied, is just not a starter.

Similarly, there are parts in the engine which are subject to steam pressure. These parts cannot be pressure tested. They must be inspected, but even on such a large engine, access is difficult and dismantling is not easy. The cylinder is secured within the steam jacket by a rust joint. Removing that without damage is a task well beyond volunteers. It is known that the 90 inch engine was put back into steam in 1976 after being cold for 32 years without any real attempt to check these aspects out. Can this approach be used on the 100 inch in 2010? I doubt it. Perhaps relief valves should be installed - but that would immediately destroy the historic integrity of the engine.

The debate continues, but restoring this historic machine, now 140 years old, as with any other 19^{th} century engine, should be given some basic thought. It is not wise to assume that all will be well simply because the engine used to be satisfactory in the privacy of a publically owned water supply organisation which, as a State body, was not even formally subject to the Factory Acts.

4. ADAPTING THE DESIGN

Apart from the canal feeders at Crofton and Cromford, no other large preserved stationary engine in the UK is, or can be, operated under its intended design conditions.

There is the cost of fuel to consider. To raise steam in Kew's Lancashire boiler, warm the system and engine up, and run the 90 inch engine for 20 minutes, currently costs £195 in gas fuel. That means 24 paying visitors have to arrive before the cost of the fuel is covered for this engine alone. There are also the usual overheads for lighting, insurance, maintenance (engine and building), domestic costs and some paid staff to run the business side of the Museum. The Museum buildings are Grade I listed and these have to be repaired to traditional standards from one-off grants and income. The damage to newly overhauled roofs, fettled with valuable lead irresistibly attractive to thieves, must be made good as the museum has just discovered. It is not cheap to play with big engines and only too easy to find that the resultant entrance fee is more than the general public are willing to pay.

A Cornish type non-rotative beam engine must have a load. It is the only way to control the rate of descent of the pump plunger. But this does not mean that the pump needs to generate a full head and nearly 50% of the weight has been taken out of the balance box. As well as reducing the steam consumption, the lighter weight reduces the tensile stresses on the cast iron beam and the wrought iron piston rod. The downside is that the engine becomes much more sensitive to handle since the vacuum is now the dominant force on the piston. An unexpected improvement in vacuum can easily lead to an overstroke and impact on the catchwing blocks. It has been done on a number of occasions - so far, without damage, but the impact of stopping around 40 or 50 tonnes of elderly cast and wrought iron by hitting a couple of wood blocks is unpleasant for the driver and visitor alike.

The big engine at Kempton Park has brought these issues to the fore. The engine/pump unit is complete - after all it is still on its original site - and the intention is to run it exactly as it was in service. There is, of course, no place for the pumped water to go. In working days it carried the waste heat away to the reservoir. Nowadays, the water is recirculated, but only a limited temperature rise can be allowed because the cast iron condenser shell is firmly located between the solid concrete wall of the pump house and the bedplate. This calls for careful monitoring.

The greatly reduced flow of steam through the engine raised unexpected problems. The inlet and exhaust valves in the cylinder covers are of the spring-loaded poppet type, actuated by tappets and push rods from the camshaft. When working, the engine took steam at 200psig (14 bar) with a superheat of 150ºF (80ºC) and the exhaust steam from the HP and IP cylinders was reheated by live steam in large receivers on the back of the engine. The power generated was a mere 1008 water horse power (750kW). The design discharge head was 400 feet (120m); now it is about 20 feet (6m). In current practice, the exhaust from the HP cylinder is about atmospheric, from the IP it is about 22 inches of vacuum (0.75 atmosphere), the best that can be raised. The designed timing of the closure of the LP exhaust valve was set far enough before dead centre to build up a compression pressure approximating to that in the IP receiver so that when the inlet valve opened, there was a smooth flow of steam into the cylinder. At the very low steam flow required for museum operation, the whole balance has been upset, resulting in the inlet valves being pushed off their seats by internal pressure and closing with a loud bang as the pressure escaped. The solution has been to gag open the inlet valves on the LP cylinder

The result of this is that 21 tonnes of piston, crosshead, connecting rod, pump rods and the ram is being driven up and down by the crankshaft. All the designer's careful balance of forces has been lost and the loads on the bearings have been increased by a factor of three or four.

These bearings are substantial. The journals are steel, the bearings themselves phosphor bronze. Lubrication is of the hydrodynamic type. The bearings should take the load but the slightest disturbance of the oil film results in severe problems which have led to cancelled steamings, much hard work and considerable expense.

The first to suffer was the main crankshaft bearing supporting the over-hung LP crank. Smoke appeared and friction slowed the engine. It was relatively straightforward to inspect the top half but the load carrying lower half could not be so easily accessed. Maintainability was not a factor in the engine designer's mind in the 1920s!

Figure 9. *Kempton engine main bearing.*

Eventually it was accepted that the lower half of the bearing would have to come out. This meant bringing in a contractor who built a frame with rolled steel joists so that the crankshaft, the LP cylinder running gear, and the flywheel could be lifted with hydraulic jacks just sufficient to take the load off the bearing. After lifting the shaft, it took a complete day to turn the bottom half of the bearing out of the bed plate. No serious damage was found and the journal and bearings could be cleaned up by hand stoning and scraping. A long and tedious job, One interesting aspect of all this was that the drawings showed that all the load carrying halves of the crankshaft bearings had oil grooves cut in them. When the bearing was finally removed, it was found to be plain. Written evidence in Worthington-Simpson's archives shows a request from their erection engineer for a new bearing and crankshaft lifting gear during commissioning. Conventional wisdom is that the load carrying capacity of hydrodynamic bearings of this type is reduced by the presence of oil grooves and this would account for the replacement bearing being plain. There is no record of further problems with this bearing during the engine's working life.

To minimise the risk of dry pick up after the winter lay-up, and reduce the time required to build up the hydrodynamic film during the frequent starts that the engine is now subject to, a horizontal drilling was put through the bearing shell at the six o'clock position with an outlet in the middle of the bearing. Prior to each start, oil is pumped in with a hand pump.

This has worked so far and there has been no further problem with the main bearing. It has simply shifted to the crank pin bearing!

During a test run in March 2009 prior to the start of the season, this bearing showed signs of distress; smoke and rapidly rising temperature. It was necessary to get another jacking system in to lift the weight of the piston, crosshead, connecting rod, pump rams and rods off the pin to allow both half bearings to be inspected.

Figure 10. *Kempton engine crankpin bearing.*

In spite of repeated scraping, adjustments, and opening up of clearances, this bearing is still overheating. It may have been damaged by rather complex factors, including too much adjustment by scraping. The engine is still being demonstrated with care, and slowly, with the bearing being monitored continually with thermocouples, but much more work, and thought, is required for this coming winter.

It is clear, from this experience, that restoring large stationary steam engines to run in museum conditions requires a great deal of understanding of the engine design. It is not just a matter for the cleaners and fitters!

5. OPERATION AND MAINTENANCE

It is comparatively easy to get a team together to restore an engine. Projects will go through the usual phases, starting with enthusiasm, descending to weariness, despair, the falling away of all but a hard core and eventually, for most projects, of reaching a triumphant conclusion. Assuming all is well and the project reaches its triumphant conclusion, what then?

Most teams, in their euphoria, look for the next engine to tackle. In the meantime, there's the recent project to run, to clean, to maintain, to cherish.

At Kew Bridge it was decided from the beginning that the museum should be open and in steam every weekend. As time went on, and more engines added, the burden on the volunteer drivers became greater. A significant number of today's drivers started over 25 years ago and it is a tribute to them that the place is still open. Many are now in their mid-seventies and older. The museum is not fighting off candidate drivers nor are there enough resources to clean and maintain the engines to the standard the old engine drivers kept in working days. The training and time commitment is a turn-off for all but a few. Perhaps a system of giving certificates to drivers setting out what engines they are passed out on and whether they are qualified to take on trainees would give some structure and reward. I have long advocated this, but it remains a good idea that might be adopted - one day. Evidence from aircraft restoration groups suggests that volunteers welcome having a log-book setting out what they can and can not do and what they have achieved. Similarly the steam locomotive support groups, so essential to the main-line operation of steam in the UK, are trained and documented. The stationary engine movement is a long way behind but it may be that some such recognition will provide an incentive to train and stay.

Insufficient training can lead to damage. There is a case for a pre-start routine and checklist being insisted upon.

Figure 11 shows the results of a careless, or inadequate, warm-up procedure on a 1910 rotative engine. And the rate at which an engine without any remaining pumpwork will accelerate requires sensitivity and anticipation in handling the throttle.

Figure 11. *Cracked LP cylinder cover*

The non-rotative engine requires close control in starting and throughout the run. There are no flying balls to keep it within bounds and clear of the blocks. Yet the driver has also to be the face of the museum, the one person that the visitor can relate to. Having the charm and patience to master this aspect is essential. Usually, it is a very rewarding experience, but occasionally the really dumb question, the Smart Alec or the nice but boring old boy with his reminiscences, can try the patience. And throughout, the driver must be aware of the length of stroke, any change in the vacuum, the boiler pressure and the whereabouts of any over-adventurous visitor. It can be demanding and requires more skills than simply an ability to start and stop the machine.

These are some of the manning problems now being encountered. Any organisation running elderly steam machinery before the paying public must be prepared to demonstrate that there is a robust training, passing out, and re-inspection system for those in charge of operating the plant and driving it.

Similarly with maintenance. It is not a surprise that the breakdown philosophy is the norm. Operations continue till some thing has to be dealt with. This has worked well – Kew Bridge has had no major catastrophes as a result of moving parts letting go, engines going out of control, or pressure parts failing. But have they been lucky?

Should there not be a regular inspection of the engines on a planned time basis on the lines of the routine surveys carried out on ships by Classification Societies and State administrations? It is not a dangerous environment, as it is at sea, but there is a degree of risk attached to the machine that could have consequences for those near to it if it fails. At Kew Bridge there is no such procedure – indeed, it would not be possible to carry it out with the resources available. Most other steam sites are in a similar situation, I believe. There may be no case for a full survey, but at least there should be a formal condition assessment at regular intervals. Kew Bridge has now been running one engine for 34 years; another has accumulated 12,000 hours. Better to have a firm understanding, before restoration has started, as to how the engine is to be maintained and inspected. At most sites, I suspect, the only target was to get the engine running with little thought to the future.

It might be said that steam sites should get together and work out some Code of Operation, perhaps through a body who could speak on their behalf to government authority. The very successful railway preservation groups in the UK have such a body, as do those who operate steam engines on the highway and at fairs. Apart from an attempt in the 80s there has been little appetite for stationary steam sites to work together in the UK. Yet, if one has a serious accident, all are in trouble. Sir Neil Cossons and his STIR initiative may well provide an answer to many of the problems. A corpus of knowledgeable advice available to groups is attractive, provided those that need it recognise their need.

6. RISKS AND RESPONSIBILITY

In the UK we act under the umbrella of the Health and Safety at Work Act 1974 and its various amendments since then. This Act imposes a responsibility on all of us to have done our best to have taken care of ourselves, our fellow workers and anybody else who might be at risk. Recent years have seen a tightening of legislation in an endeavour to ensure that those at the top, with an ultimate responsibility for running an organisation, can be held personally accountable, with criminal sanctions, when loss of life occurs.

The risks of any museum using steam as an energy source to drive moving machinery are obvious. Yet that is the attraction and raison d'□tre of the museum. Is this risk managed well enough?

The answer appears to be yes. There have been no major accidents involving the death or serious injury of a volunteer or visitor at a UK steam site to my knowledge. Nothing on the scale of, for example, the failure of the boiler of a traction engine in Ohio in 2001. There have been minor problems of course.

Incidents at UK steam museums in the last few months came very close to injuring the volunteers involved but luck was on their side. Where some groups may be remiss, and thus vulnerable, is in not having an adequate paper trail of their work to control risk.

Although some outside bodies can, and do, inspect specific parts and aspects of museum premises and plant, there is no one single overall body monitoring the operation and, in practice, each operating group is its own final inspection authority. If nothing goes wrong, there are no problems; but if something does, operations, procedures, driver qualifications, stewarding practices, inspection records, and risk assessments will come under detailed scrutiny. This is the 21st century when today's standards of safety will apply and good, documented, reasoning and records must be available. This requires serious attention and application by those with some qualifications, and the whole-hearted support of everybody else from the Chairman down.

Engines built in the first half of the 19th century are being operated by volunteers surrounded by the public. Loads have been lightened, but how can we be sure that they are safe? Are we certain that cast iron does not slowly change its characteristics in two centuries? Is there a crack developing? How much wastage has occurred? Is low cycle fatigue playing a part? What is the effect of the frequent thermal cycling on engines which were designed to run for months on end and warmed up to resume load over days, not hours? These are serious questions, yet there is a strong body of opinion amongst volunteers that sees no problems in just continuing as before from the time the engine stopped working over 50 years ago without recognising the changed running conditions, the lack of general steam expertise amongst the operators and, above all, the current legislative climate.

In a volunteer run organisation, the voice of the fully qualified engineer is only one of many. It can be swamped. There needs to be someone in the organisation who is strong enough, and well supported enough, to say "STOP. Do not continue running this plant until such and such is done". I repeat that, apart from the boiler, no outside body is likely to come in with enough understanding and authority to say just that. It is up to those involved in the project in general and the professional engineer in particular.

Usually the constraint is not technical, but financial. It requires a big personality to make the case that money must be spent to ward off a possibility, when the whole operation is on a shoe-string and the lack of money means that if the engine is not steamed, the certainty is that the income will not be there to pay for it!

Those of us with understanding of basic engineering, Strength of Materials, Thermodynamics, Metallurgy and current plant operating practices, can find it difficult to get our points across in an unstructured, democratic, environment. It can be very frustrating. It needs a strong character with an indifference to other's opinion. If that is not forthcoming, better to be out of it or, at least only take a minor role.

As a result, I concluded that, after thirty years, I no longer wished to be a Trustee, or a driver of the magnificent engines we have at Kew Bridge Steam Museum.

7. CONCLUSION

Does all this seem to be too discouraging? Those of you who have seen the John Key engine in Auckland in its motorised form and as it is today in steam will have no doubt. If you have a dormant engine near you, Go Ahead! You'll enjoy the work and the sense of achievement.

Figure 12. *Successful team at Kempton Park*

But remember that a 19th or early 20th century steam engine, however wonderful it was in its day, was worn out when it was finally stopped and must now be treated with a lot of understanding and to current legislative and safety standards if it is to be operated in public by enthusiastic volunteers under conditions well away from those it was designed for.

And be ready to answer this question after things have gone wrong.

Why did you, a qualified professional engineer, allow this to happen?

The Coorong Battery at the Winnecke Gold Mine, NT

Nigel Ridgway BEng (Mech) MBA FIEAust.

SUMMARY: *The Winnecke gold mine was one of the remotest gold mines in Australia, not far from the more renowned Arltunga mines 90 km ENE of Alice Springs in the Northern Territory, which have been extensively researched by Donovan, Forrest, Holmes and Phelts et al. An examination of the site relics and literature reveals the important links to engineering in South Australia , early steam engine technology of Hawke and Co and their national contribution to mining. It was also found that the records of Hawke are randomly dispersed and it is hoped this paper will encourage others to conserve the engineering heritage and records of Hawke and Co.*

1. GENERAL

The Northern Territory (NT) was administered by the South Australian (SA) government from 6 July 1863 until 1 January 1911 and the first gold rush was in the 1870s [1]. The Arltunga goldfield (also known as the McDonnell Range goldfield) was visited by the SA Government geologist H Y L Brown in 1888 and alluvial gold was discovered as early as 1887 [2]. Charles Winnecke explored to the north east of Alice Springs in 1878 and established a supply depot.

1.1 Historic Phase

Reef gold was first discovered at Winnecke Depot (50 km NW of Arltunga) in 1902 and ore was mined by hand at the Coorong, Junction and Reward leases, and transported to the Arltunga Government Battery and Cyanide Works for processing (in the White Range, 97 km east of Alice Springs). It was mined by the *New Coorong Crushing Company* in 1903.

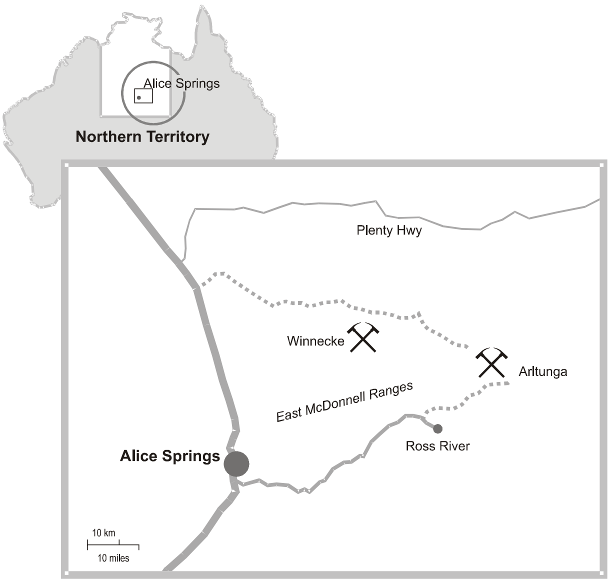


Figure 1*: Location of Winnecke Goldfields*

In May 1905 crushing with a new battery began at Winnecke and gold separation by mercury amalgamation was finished by the end of 1906.

It was a small operation and would have been managed by three people including an engine driver, ore feeder and stonebreaker. The engine driver would have several responsibilities including being the battery manager and amalgamator.

Figure 2*: Coorong battery November 1905*
[NT Library PH0763/0016]

Figure 2 shows a 10 head stamp battery in the background, boiler on the left and tailings in the foreground.

The battery was deliberately built on the side of a hill (still evident today) to cause a hydraulic gradient so that the slurry would flow from the stamp battery and over the amalgam plates. It is not known if there was any other form of concentration. It is thought that the amalgam concentrate was then transported to Arltunga for separation of the mercury amalgam and gold by retort. (Some Winnecke ore was transported to the Arltunga cyanide works between 1905 and 1906. [4])

The battery was capitalized by a private miners syndicate until 1907 when it was sold to the Commonwealth Government. Sometime after 1913 the battery was shutdown by the Administrator of the NT, on the Mining Warden’s recommendation, due to the financial losses accrued by both batteries at Winnecke and Arltunga, and the unsafe condition of the boiler at Winnecke [2].

The reported gold production between 1903 and 1906 was 968 troy oz for 703 tons of crushed ore at a head grade between 20 and 25 grams per tonne. The combined tonnes of mined ore from the Winnecke and Arltunga mines peaked in the same period (Figure 3).

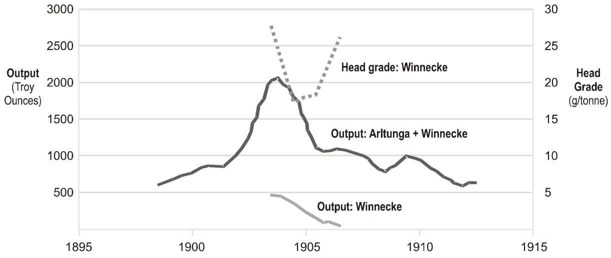


***Figure 3**: Gold production [4]*

The mine had a short life for a number of reasons:

1. Water was supplied from a well and could not meet the needs of the boiler and mining population which was up to 400 at one time. There is no surface water in the vicinity and the battery was commissioned in an arid environment. The well was sunk in 1903 and only had intermittent supply.
2. There was a typhoid health threat. The population grew from about 20 in 1902 to 300 in march 1903 and the well became contaminated by stock and four of the twelve victims died. [5]
3. The ore grade was not high enough to be profitable, and orebody discontinuous. Compared to today's methods there would have been very little planning and without the benefits of exploration drilling, development drives and mapping of the lode.
4. The SA Government withdrew its support after 30 years of patience in the NT.
5. Supplies had to be carted by camel train approx 592 km north from the SA railway at Oodnadatta
6. There was limited firewood for the boiler and fuel would have had to be transported to the battery. The wood species used is not confirmed however it is likely the cost to cut, collect and transport would have been very high for a modest energy value, and would have been less competitive than mines located near coal resources.
7. The water available was saline and high in mineral salts, resulting in rapid scale build up causing short boiler lives. The first boiler (supplied by James Martin of Gawler) at Arltunga exploded in 1901 and required replacement (by May Brothers of Gawler).

The history is typical of small gold mines in the NT commissioned with limited knowledge of the orebody and most economical method of mining. Cumming in fact found that the work by HYL Brown was of limited value to miners [2]. Little capital was available to prove the ore grade and most efficient technique of extracting the gold. This battery is unique for the NT in that the plant was manufactured by a South Australian engineering company who would have had some knowledge of the requirements. Similarly the Artlunga battery supplied by James Martin (and later May brothers) were also manufactured in South Australia. Many of the other mines in the NT were supplied by manufacturers in the UK, at greater cost and risk to the investors.

The battery has high social significance by association with the more recognized Arltunga mine and Government battery. The mines in this area were pivotal in increasing the population in the area, and social connections with Alice Springs and South Australia.

1.2 People

Key individuals associated with the mine are the Mine Warden and also the Government Geologist H Y L Brown. The miners were motivated by the potential financial returns , gold was 3 to 4 pounds per ounce, and may have earned up to 200 pounds per year. The other important individual is Henry Binney Hawke (1828-1904) from Hayle of Cornwall (home of the famous Harvey firm) who acquired an engineering business in Kapunda, SA, from J A Adamson in 1857 largely to supply the local mining industry ,WA and NT goldfields, and Broken Hill mines [6].

A sketch of the first steam engine built in Kapunda is shown in Figure 4 below and was possibly built by Hawke or Adamson.

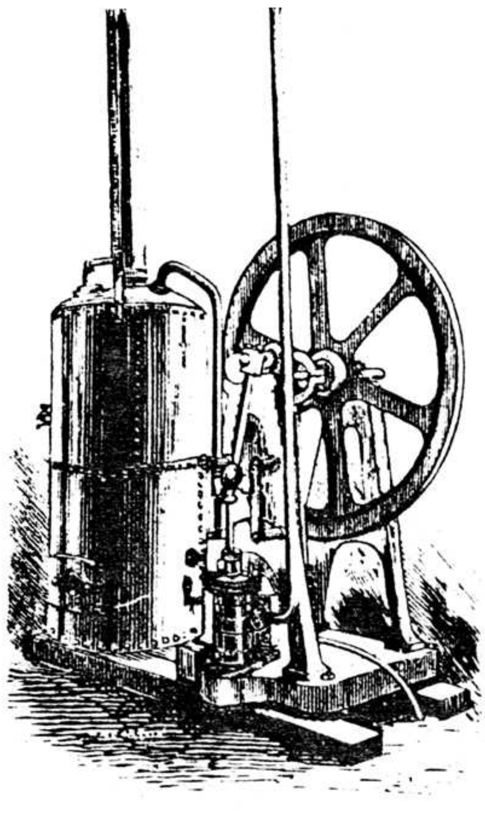


***Figure 4**: First steam engine manufactured in Kapunda*

Hawke was born at Phillack near Hayle Cornwall, and was orphaned at an early age. He was raised by smugglers and at the age of nine ran away to London and worked in a foundry. He emigrated to the colony of South Australia in 1849.

Figure 5: *H B Hawke in the pattern shop c1900 [SLSA B 58568]*

The business was sold to Rees Rees and Howard Thomas in 1884 and it is thought that Howard or Rees designed the engine for Winnecke [7]. Rees was originally apprenticed to the Fulton foundry in Adelaide and established his own foundry in Kapunda in 1883 before acquiring Hawke and Co.

Hawke worked for his first two years at Pappin and Jones foundry in Adelaide, (later Andrew Jones and Sons and Hawke supplied them with castings) and then opened his own business in Kapunda in 1866 to cater for *"farmers, millers, mine proprietors and machinists"*. Hawke designed and manufactured the first mowing machine in SA circa 1866 and was later famous in Australia for weighbridges.

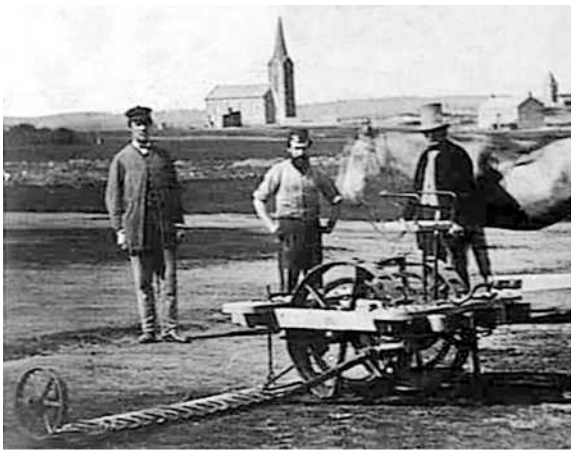


Figure 6: *Hawke's mowing machine [SLSA B 45133]*

The Winnecke mine was operated by the Gagliardi and Ciccone families in the 1930s using a 5 head stamp battery.

1.3 Technical significance

Fortunately a period photograph survives of the installation (Figure 7). The picture shows the proud engineer or mine captain in the foreground.

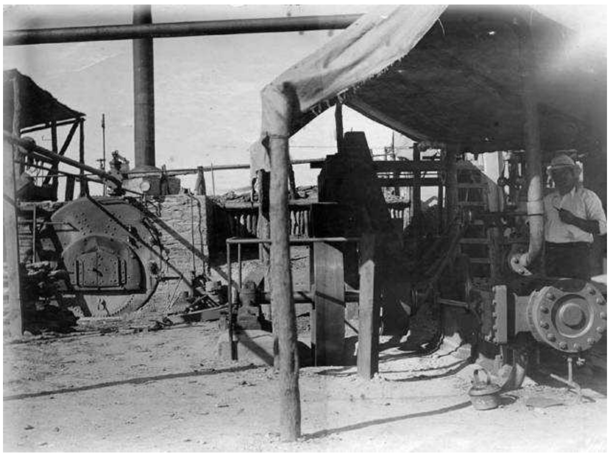


Figure 7: *Coorong battery 1905 [NT Library PH0756/0031]*

The engine was a simple non condensing right handed mill engine layout. Control was by belt driven Pickering governor without any variable cut off. The installation shows a shade structure over the engine for the engineer and safety guarding around the flywheel. The footings are a combination of masonry and concrete and substantial for the installation. The engine powered a 10 stamp battery and the boiler was supplied with well water by a reciprocating steam pump which still survives.

Figure 8: *Transport of Winnecke boiler 1900 [NT Library PH0057/0030]*

Figure 8 shows a large boiler being transported by horse team from Tarcoola to the Winnecke goldfields in 1900. Teamster of the 36 horse team was the late Steve Adams who married May Hayes of Maryvale Station (this family is a prominent pastoralist family in the NT and

SA today). Note that the boiler has the company name painted on for advertising effect. The date for the photo may be in error as it does not coincide directly with the commissioning date of 1905, unless there were delays in the installation. The description attached in the NT Library collection says the boiler is being transported from Winnecke to Alberga (in northern SA) which is in conflict with other descriptions and unlikely.

The mode of transport was common and another picture of a Hawke and Co boiler being transported to the SA Talisker mine is shown below (Figure 9). [8]

Figure 9: *Boiler transport to Talisker mine [SLSA B 17641]*

1.4 Rarity

There are very few surviving Hawke and Co engines from a well established engineering company producing steam engines from the 1860's. Their range included:

- horizontal and vertical winders
- high speed inverted verticals
- portables
- mill horizontal compound types

The other known surviving engines in Australia are a cross compound 11/20 x 24" at the Kapunda Museum, SA; a horizontal mill engine approx 11 x 25" (Victorian Scienceworks register number 1990) located in a private collection in Victoria; and a small horizontal duplex winch at Paulls Consolidated Mine, Burr Well Station, SA. From the Hawke and Co drawing register at least 27 engines were manufactured after 1897. Records before this are missing.

1.5 Representativeness

Much of the engine fabric remains and some parts of the installation and battery foundations. The site contains the concrete plinth for the engine and bedplate in situ. This is on a relatively high site with the battery being originally mounted high so the concentrate would flow by gravity over a sequence of amalgam tables to improve gold recovery. The engine is missing all of the small parts and the crankshaft, complete with flywheel, slide eccentric and governor pulley was relocated to the Old Timers Museum in Alice Springs in 1970 by the Museum Curator of the time. The engine design is late for the period which indicates Hawke & Co were reliant on existing patterns and older designs. The cast bedplate is in the bayonet pattern and the crankshaft features a cast disc crank plate. The flat bar cross head design dates back to the 1850s and requires far less machining than trunk guides. However the cylinder is overhung so some more modern principles were applied, and the number of cylinder head and slide cover bolts indicate relatively high pressure for a remote location.

1.6 Research Potential

Whilst the Winnecke battery does not have a high overall significance compared to the Arltunga battery, the Hawke engine bedplate and important civil relics of the mine remain in situ and there is an opportunity to install an interpretive sign at the site together with the crankshaft that belongs to the engine and place.

Figure 10: *Hawke and Co engine bedplate at the Winnecke Goldfields*

Some of the Hawke and Co drawings still survive at the Kapunda Historical Society museum in Kapunda and a search revealed a drawing for a 12" (bore) engine with 24" stroke and is dated 1897.

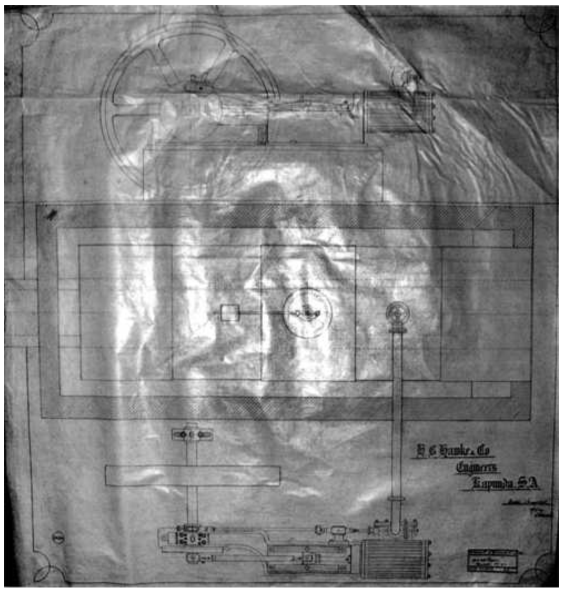


Figure 11: *Hawke and Co mill engine drawing, 1897*

The boiler and layout is almost identical to the relics at Winnecke and engine pictured in Figure 7.

An opportunity exists to scan the Hawke and Co drawings into PDF format for wider circulation, together with the surviving May drawings and brochures located at the Gawler museum.

1.8 Mill engine specification

Builder	Hawke & Co, Kapunda, South Australia
Bore	12” (305 mm)
Stroke	25” (635 mm)
Flywheel diameter	71.65” (1820 mm)
Flywheel width	10” (250 mm)
Piston rod diameter	2” (50 mm)
Crankshaft diameter	4.75” 120 mm
Boiler	Cornish type with dished ends

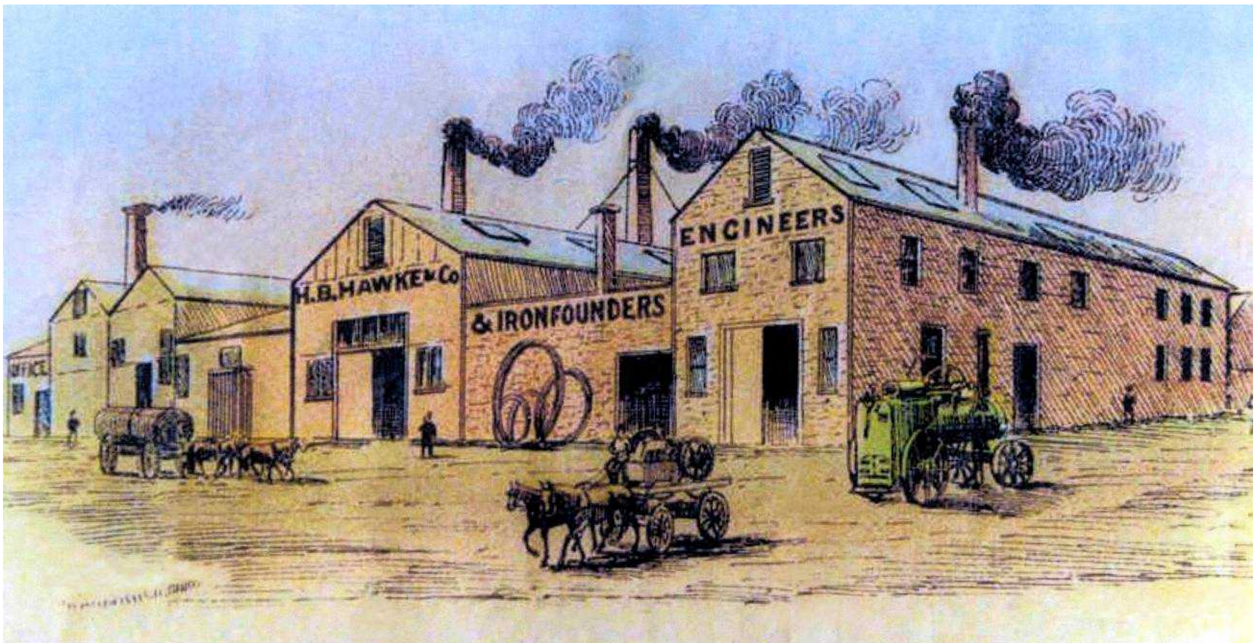
2. CONCLUSIONS

The Winnecke gold mine and Hawke and Co mill engine is a significant engineering heritage place considering the history of the mine, people, and unique combination of the period photographs, drawings and surviving relics. It is hoped that this work will encourage further conservation and interpretation of this engineering heritage.

3. ACKNOWLEDGEMENTS

Richard Venus for artwork and pictures.

Dr Bev Phelts for the encouragement to undertake this paper.



H. B. HAWKE & CO., Engineers and Iron Founders, Kapunda.

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From the Corporate Dump to a National Resource

By Tony Silke, Chair of GridHeritage, and the GridHeritage Team.

SUMMARY: *Corporatisation of the electricity industry in New Zealand produced a culture of "Out with the old and in with the new". This paper will cover the early collection of valuable artefacts from the industry, the establishment of an incorporated society to protect and store the collection, and the development of the various aspects of our activities. The GridHeritage Society now holds what is possibly the largest collection of its type in New Zealand, and it is growing steadily. The themes for this presentation will be our ongoing emphasis on achieving a high profile within the industry and on creating a resource that will be of value to future generations.*

We are slowly becoming a familiar and respected entity within the electricity industry. GridHeritage is now a trusted organisation for the safe-keeping of memorabilia and for retaining the corporate memory of the early electricity industry.

1 THE BEGINNINGS

An unfortunate by-product of corporatising the electricity industry in 1987 was the introduction of a culture of 'old is bad, new is good'. This culture idolised the new management ideals and rubbished traditional methods. Along with this culture change came the closure of numerous workplaces and the downsizing of staff numbers. Previous organisations had retained artefacts, equipment and records dating back many years. Many of these 'treasures' were found dumped in rubbish skips. Perhaps the new culture was good for restructuring the industry, although this is still being debated. What it certainly did was to provide a unique opportunity to gather and build a collection.

At the time, I was the manager of a large building and almost by accident this building became a repository for the safe-keeping of historic equipment. This presentation will describe how I was reluctantly dragged into the mysterious world of historic collecting and how GridHeritage has gradually developed as a valuable resource for future generations.

2 THE NEED TO SECURE OWNERSHIP

Many small collections in New Zealand are owned by just one person, and in the event of the death of that key person the collections are broken up and sold off. It was seen as vital that the growing collection should become an integral part of the industry and be owned by an independent legal entity. Massey University designed a paper that proposed the structure for transferring the ownership of the collection into an Incorporated Society.

The GridHeritage Society was formed in 2002 with a membership of 35 people, mostly from the industry and with some funding from Transpower. Currently, the membership stands at around 50, and there are others who regularly contribute to our work.

3 SCOPE OF THE COLLECTION

Perhaps the most difficult challenge for any small collection is to agree on its scope. Without a well defined scope the collection could become too large and lose the focus of its primary purpose.

GridHeritage's Draft Scope includes:

- Transmission equipment relating to the primary electricity system, including line construction and maintenance
- Control Centres and associated equipment
- High-voltage Substations
- Metering equipment
- Protection equipment
- Communications equipment
- Staff and the histories of people involved in the industry

Unfortunately GridHeritage, like most collections, does not have infinite storage and some of the items we would like are very large and weighty. Being the only major collection in our industry also means that we are offered equipment that does not fall within our scope. In some cases, we have accepted these donations but only if they are unique and run the risk of being destroyed. GridHeritage stores them in the hope that in some future date there will be other similar collections in the industry to accept and protect them. Examples could include a specialised power-station governor and water measuring equipment.

4 GRIDHERITAGE'S ACTIVITIES

Over the past seven years GridHeritage has become involved in a wide range of activities to ensure that the history of the industry is preserved. It is acknowledged that the Society may ultimately not be the main beneficiary of the collection. GridHeritage members accept that much of what is done is to provide a resource for others to use in the future. We do not care who holds our heritage; we simply want to know that it is in safe hands.

4.1 Cataloguing, storing and protecting the collection

After a great deal of research a standard museum software package was purchased from the USA and installed. This PastPerfect software holds descriptions of each item, along with photos and other information.[1] It is also able to be connected to web based software for an Internet site[2]. PastPerfect has been excellent for our uses and is ideal for a small collection which is managed by non-professional people. However, there are many aspects of the software that we have not used as yet. Training of users is an issue for part-time volunteers.

Figure 1 *Working on the collection at Bunnythorpe*

Currently the collection contains over 400 items that are photographed, catalogued and safely stored in a temperature-controlled building. There are hundreds of items still requiring this work which seems to be unending. There are also thousands of documents and personal collections that are stored but uncatalogued. These are held in a separate building that is equipped with temperature and humidity control. Resourcing this work is time-consuming and requires a dedicated pool of volunteers.

4.2 Oral Recording

Retired people are a major historic resource that is often overlooked. Since 2002, GridHeritage has had a goal of recording 5 persons a year. To date, we have recorded 55 persons from across a wide sector of the industry. In all cases we have used a professional oral historian to make our recordings. However, our approach to the selection of interviewees has been a little unusual. Traditionally, oral histories are made of just very senior staff. Although we have also recorded senior personnel, we have found the richest recordings have come from people further down in the organisation. We have also recorded the lives of the wives and partners of ex-staff and these have given a wider dimension to the oral histories.

All of our tapes and their abstracts are safely stored with the National Oral History Association of New Zealand in the Alexander Turnbull Library.

4.3 Maori Linemen Project

Maori Linemen have had a unique place in the development of the New Zealand high voltage transmission system.

Figure 2 *Maori line-crew*

Maori excel in this type of work and their culture adds a depth to the way they work together. The Ministry for Culture and Heritage has funded a project to record the lives of 10 Maori Linemen and their partners. It is hoped that this information will be used for the making of a documentary on the subject.

4.4 Group Oral Recording

GridHeritage has recorded groups of people who have all been involved in the same type of work over many years.

Figure 3 *Group oral recording session*

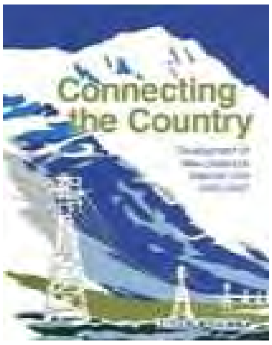
A group oral history recording session is usually more dynamic because conversations develop. One person may recall something and another adds to it and this helps develop the memory. This method has often produced better results than single interviews.

4.5 Video and Oral recording

GridHeritage has done a trial combining video/oral recording. While the use of video does add a further dimension to the oral history, the Society feels that the extra cost and difficulty involved is not justified,, except in special cases.

4.6 The book "Connecting the Country"

Transpower commissioned Helen Reilly to write a history of the electricity system in New Zealand.



This was a major work that took nearly three years of research and writing. Transpower engaged one person part-time to liaise with the author. From this work GridHeritage amassed a unique collection of industry information and photographs. Some were used in the book but most are safely stored for future reference.

4.7 Preservation of Industry Films and Videos

GridHeritage has some sixty films and videos showing the history of the transmission system and the organisations involved. Some of the early films were 8mm and 32mm and were extremely frail.

Figure 4 *Arapuni grocer's shop*

The initial effort was to copy the films onto a studio-quality video. A project was recently completed to transfer all of our videos to DVD and to a separate permanent data storage system. Our original media plus a copy of the DVD sets will be stored in the New Zealand Film Archives. The DVDs are now used for presentations to staff and for training, especially of new recruits into the industry who have not seen line construction or work in the field.

4.8 Permanent Displays

GridHeritage currently has three permanent displays of historic equipment and artefacts. The displays are all in areas that are accessible by people from the industry and they create a great deal of interest. Display sites are:

- Power System Consultants in Tawa, Wellington
- Transpower System Operation, 96 The Terrace, Wellington
- Transpower South Island Area Control Centre at Islington, Christchurch

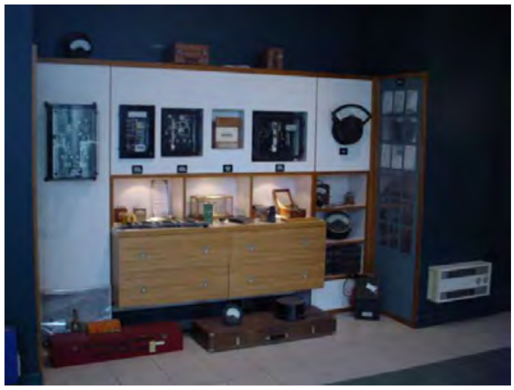


Figure 5 *Islington display*

There is a growing trend towards introducing new staff to the displays as much of the equipment comes from the days of electro-mechanical technology which is easier to understand than its modern day electronic equivalent.

4.9 Mercury-arc valve decommissioning

A major opportunity for Transpower and GridHeritage is the upcoming decommissioning of the original Inter Island High Voltage Direct Current scheme.

Figure 6 *Mercury-arc valves*

This scheme has been in service since 1965 and, at the time, it utilised world-leading mercury-arc valve technology. The benefits of electrically linking the two islands thereby enabling the transfer of low cost hydro power from the South Island to the North have been significant to New Zealand's economy.

When the mercury-arc technology is decommissioned, finding a secure way to display the valves, which are heavy, will be challenging.

4.10 The Virtual Museum

Much of what GridHeritage collects may be great value to students and to the electricity industry, but it is of limited interest to the general public. A lot of the equipment is large and heavy so difficult to display. Early on, GridHeritage members decided to work towards a 'Virtual Museum' that was easily accessible via the Internet.

One of the benefits of PastPerfect Museum software is its relative ease of building web-based displays by using its Virtual Exhibit software. This software simply picks up selected information and pictures from the main PastPerfect system and assembles them into a website. Our display is accessible from our GridHeritage website[3].

4.11 The damaged ECNZ Collection

Unfortunately, what was perhaps the most important collection of electricity memorabilia in Australasia was severely damaged in storage before it was rescued by GridHeritage.

***Figure** 7 The water-damaged ECNZ collection*

The collection came from the Electricity Corporation of New Zealand's Wellington Head Office where it was carefully put into a container, catalogued and stored in a storage shed in the South Island. Unfortunately the roof of the shed was damaged by snow and the container was left exposed to the weather. The equipment suffered extensive water damage and much of the valuable paper records were turned into a porridge-like mess.

A professional conservator was hired to provide an assessment of the damage and to assist with ongoing restorations. Almost 90% of the equipment had to be written off and dumped. One seriously damaged piece of equipment was restored and is now proudly on display in Transpower's Wellington Office. This involved the professional restoration of the cast iron base, the woodwork, clock mechanism and specialist paper conservation.

***Figure 8** The ex-Waitaki water-flow meter*

The future of the remainder of the damaged collection is uncertain, largely due to the cost of restoration and the lack of resources to do the highly specialised work.

5 RELATIONSHIP WITH TRANSPOWER

GridHeritage continues to have a very good relationship with Transpower as our work is mutually beneficial to both parties. Transpower provides office space and resources for one member of GridHeritage (myself), and I usually work four part days a week in the office. This location has been essential to keep the Society's profile high among staff and to foster the acquisition of redundant equipment to our collection. GridHeritage provides an historic resource to Transpower and is frequently used for dealing with public enquiries about historical matters.

Permanent storage for our collection is provided free of charge at Bunnythorpe, near Palmerston North, in the Transpower store which is highly secure and safe from the elements.

6 CHALLENGES FOR SMALL ORGANISATIONS

As in all voluntary organisations, GridHeritage faces difficulties in getting people to work on the collection. We rely on people wanting to be involved and in their deriving personal satisfaction from their efforts. In our case, finding volunteers is made worse by having our storage two hours drive from where most of us live. The cost of our accommodation each trip is an added drawback. We cannot see this changing in the future.

We rely on a core group of 5 enthusiastic people to do most of the work. We are also reliant on the generosity of Transpower for funding our special projects. Without their assistance we could not have achieved much at all.

7 WHERE TO FROM HERE?

In 2004, GridHeritage produced a publicity brochure that included a list of goals. Most of these goals have already been achieved, and it is now time to set some new and challenging goals.

We have gone through a change from electro-mechanical technology to modern computer technology. Previously we were able to acquire old equipment as it was replaced with newer models. Unfortunately, modern equipment undergoes little visible change although it seems to require increasingly frequent updates. Recently the System Operation branch of Transpower did a total replacement of the Electricity Market operating system. Everything has changed but the appearance. We are left with just the out-of-date procedure manuals and training documents.
Our world may never be the same.

The GridHeritage Society has an ideal place for storing equipment, but it may not be the best location for our documents and photographs. These may need to be transferred to a museum or place that is more easily accessible to the general public. Perhaps the future is for GridHeritage to collect the electrical equipment and to work in conjunction with an organisation such as The National Library of New Zealand to store the documents and photographs.

We have always felt that GridHeritage would be just one of a number of collections in the electricity industry. We envisaged an 'Umbrella' organisation with smaller collections under the umbrella. Sadly this has not yet happened.

8 CONCLUSIONS

GridHeritage has been fortunate in being involved in the industry in a time of immense change, both in technology and in the structure of the industry. We have amassed a large collection that we hope may be of value to historians in the future. Our core objectives of 'collect and protect' have served us well and will hopefully provide future generations with access to a slice of early history of the New Zealand electricity industry that would otherwise have ended up in the dump.

It is easy to think of history as a thing of the past. We must never lose sight of the fact that history is being made today, and we have to be in a position to keep adding to the collection, and ensuring its safety.

"We owe it to our Grandchildren"

9 ACKNOWLEDGMENTS

GridHeritage wishes to acknowledge the following:

- Transpower New Zealand Ltd
- GridHeritage Executive and members
- Helen Reilly
- Massey University, Museum Studies.

10 REFERENCE

Reilly, H, *Connecting the Country. New Zealand's National Grid 1886 – 2007,* Steele Roberts, Wellington, 2008.

11 APPENDICES

Footnotes:

[1] PastPerfect Software Website. http://www.museumsoftware.com/

[2] VirtualExhibit website. http://www.museumsoftware.com/ve4.shtml

[3] GridHeritage website. http://www.gridheritage.org.nz/index.html

Golden Lead – Golden Dreams

Jim Staton, Programme Manager – Historic, Greymouth *Mawheranui* Area Office, Department of Conservation.

SUMMARY: *The Golden Lead Mining Company was formed in 1890 to work a quartz/sandstone lead 10km south of Reefton. Crushing commenced 25th June 1891. In 1904 the Golden Lead company wound up, the last official figures were for 1897 when 480 tons were crushed for 196 oz of gold, representing one of the best returns in the mine's history.*

This paper describes why the battery was built, the perfect location, the energy expended and its failure. The battery remains a classic example of past gold recovery technology - set in an isolated location.

March 2008 saw the battery foundation rebuilt by the Department of Conservation, this work provided clues as to the company's demise. Essentially the aerial was too steep, the mortar boxes too deep and the 1890's speculative desire to set up another gold mine failed to recognize that this group of mines was in a relatively barren parcel of ground.

1. THE CLAIM

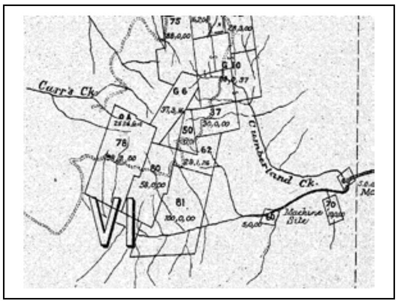


Figure 1. *Shows claims as pegged out along the ridge.*

The Golden Lead Claim is number G6, which includes claims 37, 3 and 16 – 50 is the top terminus site for the aerial ropeway - with 60 being the machinery site down in Deep Creek where the battery was built.

The auriferous formation that created this excitement consisted of sandstone intermixed with quartz leaders that was of unknown width (underground) but at the mine entrance was proven to be 18m wide. This seam was driven on for 24m across the seam to a depth of 21m with good gold found[1]

The battery was purchased on the initial strength of the trading of shares in Reefton after a trial crushing of 100 ton of quartz which produced 67oz of gold, however later crushings only produced 5dwt's to the ton.[2]

There were many calls on investors, but no returns.

2. GEOLOGY

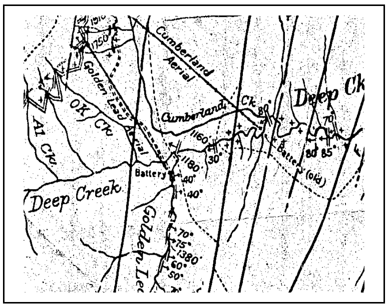


Figure 2. *The geological surface features of the area around the Golden Lead aerial ropeway. The dark vertical lines are faults.*

The broken nature of the Reefton quartz fields led to many disappointments as ore bodies tended to be fractured into short blocks of stone in most instances, the Golden Lead was different again though, still fractured but with the quartz in thin layers through the sandstone strata.

The Golden Lead Group is described by Gage in his geological report "Reefton Quartz Lodes" as "unclassified Lodes", "the relation of ore bodies to structure is not clear, but they appear to lie on the eastern side of a anticline and therefore constitute the only significant exception to the rule of structural guidance", Gage goes on to state that "in the region of the Golden Lead group of lodes, emplaced a broad zone of shearing. Through these are disseminated numerous quartz veinlets, but the group contains no ore body". [3]

This is confirmed in Henderson's report of 1918 where it is noted that "no large lode existed in the auriferous zone, which consisted of shaken greywacke traversed by numerous quartz leaders that seldom preserved their identity for more than 200ft". Henderson went onto say that "the ore was roughly sorted at the mine, but even then the yield did not cover working expenses", and that "In 1894 the plan of crushing to ore obtained from a full stoping width was abandoned, and the experiment of bagging the quartz from the leaders was tried, but proved to be no more profitable.........the company struggled along, crushing occasional parcels of picked stone, till 1903, when it merged, together with the Industry (claim) into the United Mines, a concern that went into liquidation in 1905 ".[4]

Other references note a "horse" of ground that covered some 33% of the width of the reef track, splitting the minable ground into two parts, large amounts of water was met in several parts of the mine, part of one footwall gave 20oz to the ton, but this was short lived.

The Mines Inspector of 1894 summed up the geology saying that "indeed, it may be said that the ground is too good to be given up, and at the same time not sufficiently rich to pay for working"[5]

Figure 3 below shows the structure of the sandstone rock that contained the quartz leaders. There was no quartz or gold remaining when we visited.

Figure 3. *Just inside the mine entrance, showing the sandstone formation*

3. THE STAMPER BATTERY

Built in 1886 by A & G Price of Thames for the Enterprise Gold Mining Company, Owen River[6] where crushing started in January 1887, results were disappointing and in August 1889 the battery was advertised for sale. (Appendix A.)

The Golden Lead Mining Company purchased the battery; prior to the battery arriving on the Big River Road high above Deep Creek the company had felled a strip down the 1km distance towards the battery site, reportedly using a flying fox to get all the components down to the site[7].

Crushing commenced Thursday 25th June 1891. When the inaugural crushing of 500 tons was completed, the result, 127oz of gold was a huge disappointment[8].

In 1904 the Golden Lead Company was wound up, the battery had been idle for some years, the last official crushing figures were for 1897 when 480 tons were crushed for 196 oz of gold, representing one of the best returns in the mine's history. The Golden Lead joined forces with adjoining claims but all were wound up the following year.

Several people worked the mine at various times on tribute without success, the last parcel of 18 tons mined by Messer's Sweeny and Leggoe early in 1908 returned 24 ounces by amalgamation. This was crushed at the Big River battery for a value of £96.[9]
The adjoining New Big River Company bought the claim and equipment in 1908, it was not utilized. An offer of £600 for the battery was accepted in 1919 from one Arthur Mitchell, a boot maker from Christchurch, the battery never ran again.

During the late 1930's/early 1940's the battery was saved from scrapping due to its isolation assisted by a wiry little gorge on the downstream side, and the long 60 degree slope back to the Big River Road above.
In March 2008 the battery foundation was restored by Department of Conservation staff, this involved stabilizing 13 ton of metal in mid air while placing eight ton of timber under the battery. Isolation, heavy timbers and suspended metal provided safety, logistical (and authenticity) issues to overcome, much the same as when the battery was built in 1890.

During the restoration the first clue as to why the stamper battery never lived up to expectations came to light – the sequence of drops as per the settings of the cam lifters is out of sequence. A casual glance at the battery shows nothing out of the ordinary until one realises that four cams are set at the same place, then another four, then two, so the drop is 1,5,6 & 10 together, then 2,4,7 & 9 together followed by 3 & 8 together - an unusual sequence indeed.

The usual sequence of drop is 1,8,4,10,2,7,5,9,3,6 or similar at between 85 to 95 beats per minute[10]

All is made clearer upon finding that the mortar boxes were too deep for the material being processed.

Researching in the Papers Past web site the Inangahua Times newspaper came up with the truth of the matter:
"Considering that the stamper boxes are deeper than usual in this field, and also that the soft nature of the stuff operated upon does not cause the same amount of splash against the gratings as under ordinary circumstances, with the natural consequence that less quantity of gold is forced through and onto the plates,

the show of amalgam on the plates is such as to justify the reasonable expectations of a fair yield".[11]

The Grey River Argus newspaper also commented that: "It seems that as soon as the stuff was put into the stamper boxes it was quickly reduced to the conduction of mud, and instead of being splashed through the gratings, as in the case of quartz sand, it merely oozed through the apertures, and so thickened the water that fine gold must have been held in suspension and so passed over the tables without coming into contact with the silvered tables".[12]

The fair yield was only achieved by careful selection of what travelled down to the battery in the aerial buckets, and looking at the annual returns this was not achieved too often, as it turned out much of the material was crushed at the Sir Francis Drake and other nearby batteries that were close to the Big River Road.

The official figures show that between 1890 and 1907 11,344 tons of ore were processed realizing 2,653ozs (75kg) of gold. The mine operated for 12 of those years and three years, 1892 to 1895 produced 10,293 of that tonnage.[13]

4. THE IDEAL SITE - FOR A STAMPER

The juxtaposition of creeks, topography, large red beech trees and aspect appeared to be in the companies favor.

Sited near the confluence of Golden Lead and Deep Creeks the battery sits on a gentle slope down to the flat camp site area. This area also had an abundance of large virgin forest Red Beech trees eminently suitable for stamper battery foundation bed logs.

Upon surveying the site it became clear that the direction of felling the trees chosen for the bed logs was the same angle as the second part of the pelton wheel water drainage ditch. The stumps and remains of the heads of the trees are still visible, therefore it is concluded that the pitsaw site for the sawing of the battery foundation bed logs were prepared in that part of the ditch. Other factors included that they would not have wanted to fell the trees into Golden Lead Creek, or the stamper building or camp parts of the site.

The small ridge that runs up behind the battery is just at the right slope to position the ore bins without a great deal of preparation, and gives enough elevation not too distant from the back of the bins from the aerial ropeway terminus. This ridge also gave enough height for the aerial ropeway to span a greater distance across the valley, reducing the number of towers required.

The slope of the hill above the battery building site and up to the water race that runs just below and parallel to the Big River Road is perfect for the iron pipe supplying water to the pelton wheels.

All in all the ideal site, with road access already established to just below the mine, no need for aerial working assistance due to the angle of the drop-off, and plenty of available water supplies.

5. THE AERIAL TRAMWAY

The aerial tramway rope was purchased from the Lone Star gold mine which ran from their mine to the Just-in-Time battery, (Boatmans Valley, 16km north of Reefton).[14] It appears that the Owen River rope was too short for the job, and as it turned out the Lone Star aerial rope was also too short and the Golden Lead company had to purchase new rope from Wellington.

The Golden Lead aerial tramway was constructed by one Mr. Kruzenga. A newspaper article of the time noted "The erection of the aerial tramway is progressing well, and Mr Kruzenga expects to have his contract completed well within the specified time." [15]

"The Golden lead line has a total fall of 1000ft, (304m) in 66 chains (1328m) horizontal; this would give 4,469ft (1362m) nearly as the hypothenuse (sic), doubled equals 8,938ft (2724m); the actual length of rope when in good working order is 9,012ft (2747m), or equal to an allowance of 74ft (22.5m) for sag both sides.[16]

By 1890 it was noted in the same newspaper that "Surveys go to show that the fall from the mine to the Deep Creek battery site is rather much for the safe working of an aerial tramway line, and it is probable therefore that the line will have to be lengthened to some extent beyond what is actually necessary to connect the two points, in order to get rid of some of the fall. The matter is now under consideration".[17]

The building of the aerial tramway was not without difficulty, another article in the Inangahua Times noted "The inclement weather has retarded operations in connection with the completion of the aerial tramway, which is the only unfinished portion of the crushing plant and appendages. Since the snow and rain ceased the frost has hindered the work, which would only require a few fine days to complete. After the wire rope had been spliced the contraction caused by the cold placed such a strain on the shaft of the terminal sheave that it bent, but fortunately a stronger one had been provided as a reserve, so that no great delay occurred on that account". [18] The aerial tramway tested mid-June 1891 with the battery commencing crushing late June.

Following the aerial rope down the hill to the stamper battery one comes across several shallow cuttings on the up hill (the full bucket) side of the ropeway. It is obvious that the mine still had issues with buckets hitting the ground with loose quartz visible in a couple of locations.

The grade of the aerial tramway was reported as 1 in 4.36 and was capable of transmitting 35cu yards in eight hours – but the best grade was 1 in 7 [19]. Due to the location of the battery this was impossible to achieve, there was talk of extending the aerial and though not confirmed section 70 appears to be the next logical place to build the battery, this never eventuated.

However, it is assumed that the company either changed the surveyed route up the gully to make the route longer and more gradual (this could account for the 30 degree difference in compass bearings between the plan and what's on the ground), as the distance from the terminus to the back of the stamper battery is some 25m further away than the recommended distance in the 1896 AJHR report.

Les Wright found no buckets remaining on the downhill (empties) side of the aerial, during a second inspection of the line we found five buckets on the uphill, or full side. The conclusion was that the New Big River Gold Mining Company had purchased the Golden Lead machinery and claim essentially to have access to spare aerial tramway parts – as their aerial tramway was exactly the same in every detail.

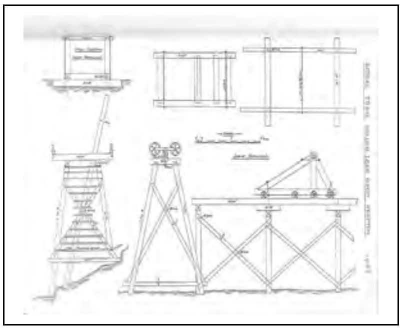


Figure 4. *Drawing of a tower and the battery terminus*[20]

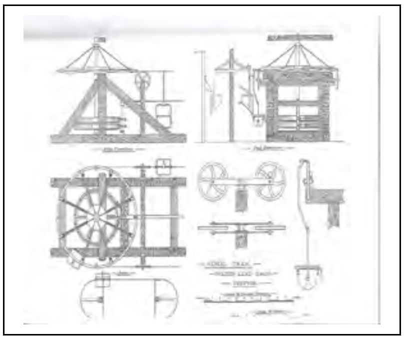


Figure 5. *Drawing of the top terminus and loading facilities*[21]

The Mines Report of 1896 in the Appendices to the Journals of the House of Representatives has a full description of the aerial tramway.

6. CONCLUSIONS

1. The speculative effect on prospective shareholders was huge at the time of prospecting the claim, with shares rising from 10 pence in November 1889 up to a high of 11 shillings prior to the first crushing of ore in June 1891 – with the poor results shares soon dropped back to around 2 shillings. My contention is that it was this initial euphoria that lead to the purchase of the 10 head stamper battery.

2. The availability of the cheap Owen River stamper battery coincided with the desire of the company to have their own stamper battery, however, it appears that the Owen River battery was not inspected prior to its purchase, it was purchased sight unseen.

3. The ground was not prospected sufficiently to prove the resource, there was plenty of speculation, but reading the reports suggests the "horse" rock intrusion presented problems not foreseen by the prospectors, or the Golden Lead Gold Mining Company.

4. The depth of the stamper battery mortar boxes combined with the quartz/sandstone material being crushed was to become a major issue as the material crushed turned to a mud consistency resulting in no splash, "pugging up" and not travelling through the screens, much fine gold was lost being suspended in the muddy water that flowed over the top of the mercury table into the sludge channels.

5. The aerial tramway was deemed at the time of construction to be too steep and an alternative site further down Deep Creek was looked at for the terminus but not pursued. Several small cuttings had to be cut into the uphill side of the aerial to stop the buckets hitting the ground. These factors would have lowered the optimum bucket speed, reducing the volume of ore transported to the battery.

6. This gold mine was up against it from the very start, what looked to be a promising gold mine with a stable long term future turned out to be a dismal short lived failure, however it has left a legacy of a stamper battery, aerial ropeway, the mine adits and associated tracks which are in very good condition, these will provide interpretive insights into this and other gold mining activities in the Reefton area.

The Golden Lead stamper battery is to become part of the proposed "Reefton Goldfields Journey" being promoted by the Reefton Community Board with assistance from the Department of Conservation.

This initiative is a walking/mountain biking experience over some 45km that will run between Waiuta in the south to Capleston in the north utilizing mine pack tracks, water races, heritage sites and good hut accommodation along with proposed transport by local companies.

The next project is another stamper battery on this journey, the Lord Brassey.

7. ACKNOWLEDGEMENTS

Les Wright, NZAA file keeper, Historian and writer of several local history books surveyed the Golden Lead mine, aerial tramway, pipeline and battery sites, Les was the on-site archaeologist while we replaced the stamper battery foundation timbers and has contributed with comment and advice to this paper.

8. APPENDIX

Appendix A[22]

For Sale.

THE TEN STAMP QUARTZ CRUSHING BATTERY PLANT as it is now erected at the Enterprise Mine, Owen District, Nelson, consisting of

Ten head 8cwt stamps, with all belting, shafting, gearing, pelton wheels, electro-plated copper, and blanket tables, &c., &c. (makers A. and J. Price, Thames), together with 10 berdans fitted with Adams and Forth's patent drags driven by separate pelton wheel with all accessories, the whole in good going order; also, the whole of the mining tools and stores, together with the tools and contents of the blacksmith's shop and battery store. One case of large-sized (4) electro copper plates (new), iron safe 28 x 25 x 28, set of gold scales and weights (½dwt to 128oz), enamelled buckets, dishes, &c., six bottles of quicksilver, blocks, ropes, chains, &c. Iron delivery pipes in 16ft lengths, 2ft x 2ft, connecting head race with the battery, &c., &c.

The battery has only crushed about 1200 tons in all, and is as good as new, offering a rare opportunity to any Company to acquire a Crushing Plant at Low Cost. The expense of cartage from the present site to Nelson would be about £7 per ton. A very Low Price would be accepted for the lot, and terms could be arranged. Detailed specification will be forwarded on application.

Apply to

CUFF AND GRAHAM,
Christchurch.

9. REFERENCES

[1] Mines report, 1889, (C2:113-114).*Appendices to the Journals of the House of Representatives, (AJHR).*

[2] Mines report, 1892, (C3:56; C3A:24), *AJHR.*

[3] Gage, Maxwell, M.Sc. 1948, *The Geology of the Reefton Quartz Lodes*, Wanganui Herald Newspaper Co Ltd, Wanganui.

[4] Henderson, J. 1917, *The Geology and Mineral Resources of the Reefton Subdivision, Westport and North Westland Divisions, Bulletin 18, New Zealand Geological Survey, Department of Mines.*

[5] Mines Report, AJHR, 1894, (C3:77)

[6] Sited in the upper Buller River, some 110km away from the Golden Lead site by road. DOC GIS Mapping.

[7] *Pers comms,* Staton/Lockington, 1975, (nephew of the wagon driver who transported the equipment), oral history session, Reefton.

[8] Inangahua Times Newspaper Various editions through July 1891, *Papers Past, National Library of New Zealand*

[9] Mines Report, AJHR, 1908, (C3:26)

[10] Wright, Les 1993, *Big River Quartz Mine.* Friends of Waiuta, Craig Printing Co., Ltd., Invercargill

[11] Inangahua Times Newspaper, 02nd July 1891, *Papers Past, National Library of New Zealand*

[12] Grey River Argus Newspaper, 13th March 1892

[13] Henderson, J. 1917, (165) *The Geology and Mineral Resources of the Reefton Subdivision, Westport and North Westland Divisions, Bulletin 18, New Zealand Geological Survey, Department of Mines.*

[14] Inangahua Times Newspaper, 24th June 1889, *Papers Past, National Library of New Zealand*

[15] Inangahua Times Newspaper, 1st April 1889, *Papers Past, National Library of New Zealand*

[16] Mines Report, AJHR, 1895, (C3:252)

[17] Inangahua Times Newspaper, 6th October 1890, *Papers Past, National Library of New Zealand*.

[18] Inangahua Times Newspaper, 15th June 1891, *Papers Past, National Library of New Zealand*.

[19] Golden Lead Mine - Specification for Aerial Tramway, 1895, (C-3:252), *AJHR.*

[20] *ibid*

[21] *ibid*

[22] Inangahua Times Newspaper, 1st July 1889, *Papers Past, National Library of New Zealand*.

The Engineering of "Engineering a City".

Richard Venus, BTech, BA.

SUMMARY: *The South Australia Division of Engineers Australia has recently produced a small guide to the engineering heritage of the City of Adelaide. The publication supports the "Looking Back" theme of EA's 90th year. Although little physical evidence of Adelaide's engineering heritage remains, the research for the booklet uncovered many more sites than were expected. This paper describes the planning process and provides a brief summary of the heritage aspects covered.*

1. GENERAL

About 20 years ago, my colleagues Deane Kemp, the late Dr John Pickles, and Arthur Ward produced *Adelaide - Engineering and Industry* for the South Australian Division of Engineers Australia. It was based on a 20 item Walking Tour devised in 1983 by the Division's Committee on Engineering Heritage[1].

A few years ago, the Engineering Heritage & History Committee took a new approach. The idea was to organise the information, not by geography, but by the requirements of the community: what engineering infrastructure did those first Colonists need in order to establish their settlement and build their capital city?

2. A BRIEF HISTORY

The Colony of South Australia was proclaimed in 1836. The site for its capital, Adelaide, was chosen on rising ground about six miles from Holdfast Bay where the first settlers had landed (Figure 1). Colonel William Light, the Surveyor General and the Colony's first engineer, had to lay out a city plan which defined blocks or Town Acres. This pre-planned rectilinear layout makes Adelaide different to other cities which evolved from *ad hoc* settlements.

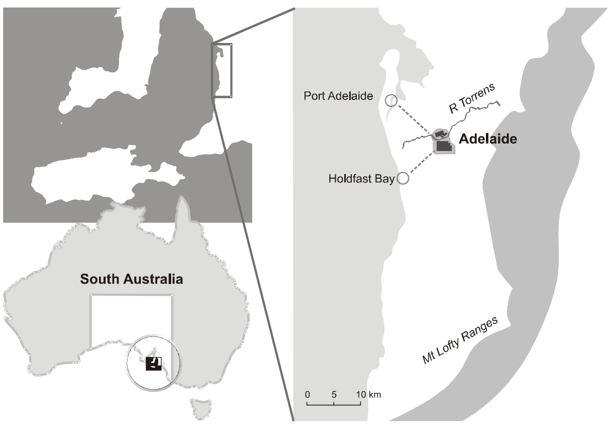


Figure 1. *Location of Adelaide*

The route between Port Adelaide and the City was a well-travelled one and, not surprisingly, was also the path followed by the first significant road, the first telegraph line, and the first railway.

3. A HIERARCHY OF NEEDS

In 1943, the American psychologist Abraham Maslow postulated a theory of human motivation[2]. He later developed this into his well-known model of a hierarchy of needs (Figure 2) which states that basic needs have to be adequately satisfied before higher order needs can be developed.

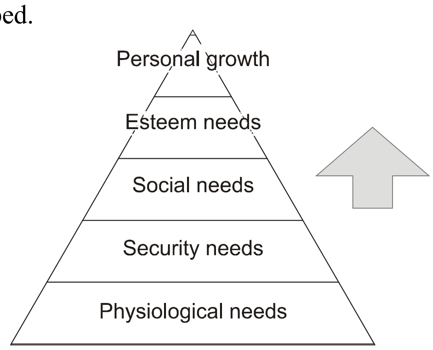


Figure 2. *Maslow's Hierarchy of Needs*

We realised that the early colonists had a similar pattern of needs (Figure 3). First they had to secure a supply of water and food, build shelters, and find fuel for warmth and cooking. Satisfying these needs required the development of engineering enterprises and infrastructure – water supply, food production, buildings and construction, and so on.

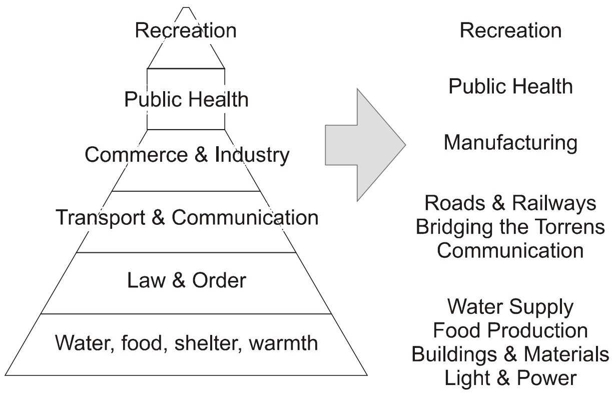


Figure 3. *Colonists' Hierarchy of Needs*

Once these needs were met, they could turn their attention to developing more complex aspects of infrastructure such as transport and communication.

4. WATER SUPPLY

The Torrens was the principal source of Adelaide's drinking water; however, it also became the bathroom, sewer, swimming pool, and rubbish dump.

Town Clerk Thomas Worsnop said[3]:

> … few cities in the world were worse supplied than Adelaide. The inhabitants were compelled to depend upon water-carts, the drivers of which dipped the water out of the river and brought it to the houses …

4.1 Water Carting

The price charged by the water carters depended on the distance from the river so that the City developed in the streets nearest the southern banks and not the centre, as Colonel Light had envisaged[4]. The water carters had to enter the river to fill their barrels. This meant that, not only were they polluting the water, but their carts were damaging the banks. In 1852, two firms installed pumps to raise water into holding tanks from which the carters could fill their barrels.

4.2 Adelaide's reticulated supply

In 1855 the Surveyor-General presented a report which recommended a storage option upstream on the Torrens at Thorndon Park[5]. The scheme had to be able to supply 800,000 gallons of water a day. A weir ten feet high would be built across the Torrens and a 20-inch pipe would conduct water to an off-stream reservoir. From here an 18-inch main would bring water to the City[6]. The weir was completed in June 1858; however, it was found to leak and an entire new weir had to be built. Water was first supplied on 28 December 1860[7].

4.3 Extending supply

Additional storage reservoirs were commissioned: the first of these was at Hope Valley which took water from the same weir as Thordon Park. Work on the new reservoir and aqueduct was completed in 1872 and water from Hope Valley was first supplied on 6 November that year[8].

As the suburbs grew and water supply was extended, holding or service reservoirs were constructed in the Adelaide parklands. A reservoir near the intersection of Barton Terrace and O'Connell Street was built in 1878 and is still part of the water supply system.

The Glenelg service reservoir, near the intersection of East and South Terraces, was built in 1881. The drawings show an earth-covered mass concrete roof supported by curved corrugated iron sheets carried by iron girders resting on 58 cast-iron columns.

In 1928 the reservoir was taken out of service and in 1982 it was filled in although the size and shape of the original structure can still be seen. Sections of the original wrought iron fence still stand around the adjacent croquet club. Nearby is cast iron bench mark #10 (see Section 4.5).

4.4 The Valve House

The Valve House, built in 1857, contained the valves which controlled the supply of water. In 1974 the Engineering & Water Supply Department (E&WS) decided to transfer its operations elsewhere. The Valve House was relocated and rebuilt using the original materials. This was completed on 6 December 1982[9] and the structure is now the only reminder of the workshops and works depot which once covered 3½ acres.

4.5 The cast-iron benchmarks

More than 30 cast iron bench marks were placed at key locations in and around Adelaide in 1879. The castings are about 1.2 metres high with a cast bronze plate showing the corresponding level. Many were removed when roads were widened but four remain within the boundaries of the City.

5. FOOD PRODUCTION

The basic diet of the early settlers was bread and water. The Torrens provided the water and in time the fertile soils of the Adelaide plains provided grain. This led to the establishment of two important industries in the City – flour milling and brewing. Many manufacturers proudly advertised their use of steam-powered equipment and were among the first to introduce gas (from the 1860s) and then electricity (from the early 1880s).

5.1 Flour Milling

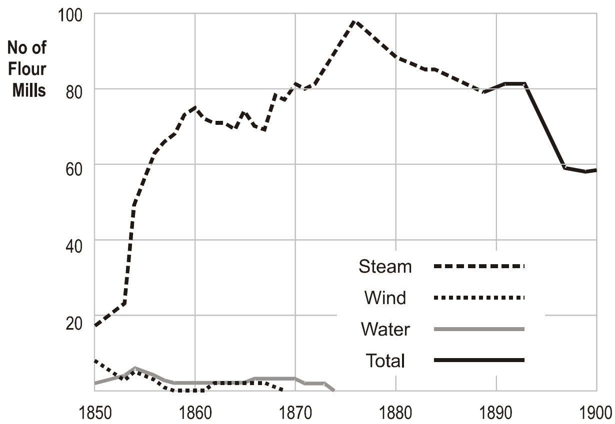


Figure 4. *South Australian Flour Mills, 1850-1900*

The growth in the wheat crop required a corresponding increase in the number of mills needed to grind it into flour (see Figure 4, based on Table 1 in Harrison[10], derived from *Annual Returns of Flour Mills*).

Nine of these mills operated within or just outside the City. Most were built from the mid-1840s to the mid-1850s and some operated until the mid-1870s (Table 5.1).

Table 5.1: Adelaide City Flour Mills

Mill	Location	TA*	Years
Dr Kent's	Kent Town	--	1841 - 1845
→Albion	Grenfell St	107	1846 - 1866
City/Malin's	West Tce	464	1842 - 1851
Company's	Hackney	--	1842 - 1875
West Tce	Waymouth St	186	1842 - 1876
Cain's	Currie St	139-140	1843 -1849
Crown	Wright St	454	1852 - 1876
Clark's	Halifax St	564	1854 - 1859
Light Square	Waymouth St	195	1854 - 1876
Imperial	Hurtle Square	494	1856 - 1881

*Town Acre

The Albion Mill
Dr Benjamin Kent set up a mill just east of the City in 1840[11] and in 1845 moved it to a new building in Grenfell Street[12]. In 1857 Kent sold the mill to George Sismey who gave it the name "Albion". The machinery was eventually moved to Gawler[13].

The City (Malin's) Mill
The first flour mill built in the City was a windmill completed in August 1842[14]. The whole building and much of the mechanism had been made from local timber. It had ceased operating by 1852 when it was described as "dilapidated" in the rate assessment[15].

The West Terrace Mill
In 1842 the architect George Kingston was commissioned to design a windmill. Built of brick, the six storey tower stood 50 feet tall. In 1845, the mill was struck by lightning which destroyed the sails and windshaft[16]. The proprietors then decided to convert the mill to steam power[17]. In April 1876, a fire broke out and destroyed the mill[18].

The Company's Mill
The South Australian Company had imported mill machinery in 1838[19] but didn't erect the mill until later[20]. The mill commenced operations in 1842 and the following February exported the first flour from the Colony. The plaque on the site says the mill was demolished in 1875.

Cain's Mill
Thomas Cain operated a steam mill in Currie Street. *The Southern Australian* noted that "… it is very notorious in the city, for it may be truly said that … its voice is *ever* heard."[21] It was originally a saw mill powered by bullocks. The mill was later demolished to make way for the Elders Smith & Co building[22].

The Crown Flour Mill
This mill was built at the eastern end of Wright Street about 1851/52. It is the only mill to have left its mark on the City by having a street (Mill Street) named after it. Later it became known as the Verco Mill.

The Light Square Mill
Built by George Wyatt (one of the sons of John Wyatt) in 1854, it was described as a roller mill and was powered by one of Wyatt's own steam engines. It was operated for a while by his brother Henry. John Marchant leased the mill and ran it from 1864 to 1870[23].

The Imperial Flour Mill
William Elliott's grand mill on the corner of Carrington Street and Hurtle Square was launched in fine style with a slap-up dinner at the Freemason's Tavern on Wednesday 14 May 1856[24]. The building was "huge", the engines "powerful", and the store room "extensive". In 1860 the *Observer*[25] said that the Hurtle Square steam mill had not been in operation for some time. The building was later used as a tobacco factory.

Clark's Halifax Street Mill
By April 1851, William Henry Clark had completed a substantial brewery. Towards the end of 1853 he started building a large factory to manufacture ship biscuits[26] and also built a steam flour mill. The mill and brewery buildings remained untenanted for many years and fell into disrepair[27]. The five-storey mill building, said to be one of the most imposing structures in the Colony, was subsequently adapted to house the City's rubbish incineration plant (see Section 12.2).

5.2 Brewing

A number of dedicated breweries were established within the City itself (see Table 5.2) and two are still standing.

Table 5.2: Adelaide City Breweries[28]

Brewery	Location	TA	Years
Adelaide*	Wyatt St	--	1844 - 1902
Anchor	Morphett St	--	1855 - 1883
Dragon	South Tce	--	1871 - 1901
Enterprise	Waymouth St	--	1885
Grenfell St	Grenfell St	--	1839-1840
Clark's	Halifax St	564	1843 - 1863
Hindley St	Hindley St	--	1843 - 1847
Lion*	Jerningham St	987	1872 – 1914
Melbourne St	Melbourne St	--	1840 – c1858
Primrose	Union Lane	--	1844 - 1902
Torrens	River Torrens		1837 – 1843
Victoria	Holland St		1889 – 1919
West Adelaide	River Torrens		1838
West End	Hindley St		1859 – 1888

* Structures still standing

Adelaide (Pirie Street) Brewery
The original Pirie Street Brewery was built in the early 1840s. More cellarage, stores, a malting floor and malt kiln, and bottling rooms were added in the early 1870s. All these extensions were designed by Adelaide architect Daniel Garlick[29]. The buildings still stand and have been converted to professional offices.

Clark's Brewery
William Henry Clark built and operated his Halifax Street Brewery from 1843 until 1857 when he began leasing it to various operators.

The Lion Brewery
In March 1871 tenders were called for the construction of a brewery at North Adelaide. It took a year to complete and began operating as the Lion Brewery. The brewing section was closed in 1914 but the company continued to produce soft drinks[30]. In 1970, the brewery buildings were converted to apartments and the adjacent hotel is still trading.

The West End Brewery
The West End brewery was established by the hapless William Clark in 1859; the following year he went broke. The brewery was eventually taken over by the South Australian Brewing Company. All brewing operations were transferred to the Southwark Brewery and brewing ceased in the City in 1980[31]. The West End premises were demolished in 1983[32].

6. BUILDINGS & MATERIALS

House building began in earnest when settlers took possession of their freehold land in March, 1837 … able-bodied men and women set to work using simple materials close at hand … [33]

6.1 Early building materials

One of the first buildings to be erected in the Colony is still standing and still in use. It's one of a number of prefabricated Manning Houses brought to the Colony in 1840. No more than a dozen metres away, a companion Manning house, encased in brick soon after its assembly, is also still in use[34].

6.2 Ever-taller buildings

As new engineering materials became available, the sky was quite literally the limit for buildings but social and aesthetic concerns led to height restrictions being imposed[35]. In 1911, the South Australian Government commenced a review which resulted in the *Building Act 1923*. The limits it imposed remained in force until a new Act was passed in 1961[36].

6.3 Reinforced concrete construction

Kither's building
In 1907 work began on one of the first reinforced concrete buildings in Australia. This five storey building had an impressive façade and balcony; however, these were removed in 1960 and all the significant structural features of the building have been hidden. The structural design was by John (later Sir John) Monash; however, it was not all built with concrete – some steel was used[37].

The Verco building
In August 1911, plans were prepared for Adelaide's tallest building which was built in two stages with the taller back (southern) section being built first[38]. The structure was designed by Monash's South Australian Reinforced Concrete Co Ltd who noted the "lofty nature of the structure"[39].

The T&G building
The T&G building was opened 23 November 1925. Its composite steel and reinforced concrete frame enabled it to reach the City's height limit of 132 feet; it was also the first to boast a full system of ventilation and electric lighting.

6.4 Steel-framed construction

The MLC building
After World War II another insurance/assurance company built Australia's first glass curtain wall building. The newspapers called it the "Light House" but it's now referred to as Beacon House for the distinctive MLC weather beacon which was removed in 1979.

6.5 Vertical transportation

Several hydraulic lifts powered by the City water supply were installed in City warehouses and in the Bank of South Australia building (now Edmund Wright House)[40]. The first electric lift was installed in "Electra House" (see Section 10.4) in 1905 and was supplied by the Otis Elevator Company[41].

6.6 Preservation of buildings

The former Bank of South Australia building had many notable features and was saved from demolition in 1971 when the State Government bought the property[42].

The Marine & Harbours Board building was opened in 1884. When the land was needed for the construction of a building for the State Government Insurance Commission, lateral thinking resulted in a lateral solution to save the façade from demolition. On 8 December 1979, the 1000 tonne structure was moved 34 metres north on steel rails using hydraulic rams[43].

7. LIGHT & POWER

7.1 Mechanical power

The first "home-made" steam engine was the *Cyclops* completed by George Wyatt at his father's Grenfell Street foundry on 8 September 1843[44].

7.2 Town and Natural Gas

One of the earliest reported gas lighting installations was at the Freemason's Tavern: it was "brilliantly illuminated" on the evening of Monday 7 September 1846 with gas produced on the premises by a plant made by John Wyatt's foundry[45].

The South Australian Gas Company (SAGasCo) was not formed until 1861[46]. They built a gasworks at Brompton and regular supply to consumers began on 22 June 1863. Supply was extended to North Adelaide on 23 May 1864 and to nearby suburbs soon afterwards.

Demand was such that a second gasworks was completed at Port Adelaide in November 1866[47].

7.3 *Street Lighting*

Street lighting was a haphazard affair until the gasworks opened. Even then it was several years before the Council signed a contract with the Gas Company in June 1867[48]. However, of the 285 lamps erected, the mains had only been laid to 115 of them; the others were lit with kerosene[49].

The Council installed their first electric street lamp in 1895; the arc lamp at the intersection of Hindley and Rundle Streets was supplied from the nearby Theatre Royal[50]. A few years later the Council signed a contract with the South Australian Electric Light and Motive Power Company (SAELMP) and 31 arc lamps were lit on the evening of 4 January 1900[51]. Gas lights continued to be installed until 1913 but had all been replaced with electric lamps by 1921.

7.4 *Electricity Supply*

SAELMP built a power station near East Terrace. The station didn't officially open until 19 November 1901 so the Company supplied street lighting and other customers from a temporary power plant[52]. On 31 August 1904 the undertaking was sold to the Adelaide Electric Supply Company (AESCo) which, over the coming years, became South Australia's main electricity supplier[53].

In 1902 AESCo installed motor generators to convert direct current (DC) to alternating current (AC) which enabled supply to be extended further[54]. Later, when AESCo built a new AC power station near Port Adelaide, a converter station was built to maintain DC supply in the City; this opened on 30 August 1925. A few years later, almost all the DC loads in the City had been converted to AC but a skeleton DC supply was maintained from a rectifier station until 3 January 1967[55]. The MTT (see Section 8.3) also built its own converter station in 1907 to supply DC for the tram network. An Historic Engineering Marker was placed at the power and converter stations on 6 April 1995

8. ROADS & RAILWAYS

8.1 *Road making*

King William Street was the first properly-made road in the City, prepared with sand from the Torrens and limestone gravel from the parklands quarries in 1842. In 1895, possibly for the first time in Australia, some of the side streets were dressed with tar, a by-product of gas production[56]. Better results were obtained using distilled tar and the Council installed its own plant at the destructor station in 1911 (see Section 12.2).

8.2 *Railways*

In 1856, the first State-owned steam railway in the British Empire began operating between Adelaide and Port Adelaide[57]. The consulting engineer was Isambard Kingdom Brunel and the original rails were therefore the same bridge or hollow type used on his Great Western Railway. Unfortunately they proved unsuitable in South Australia's hot dry climate and, by 1868, had all been replaced[58]. Three locomotives were imported from England and the line opened for general traffic on 21 April[59]. The line was duplicated in 1881[60].

The first Adelaide Railway Station opened in 1856. It was extended several times and then replaced with today's building which opened on 28 June 1928.

8.3 *Tramways*

Adelaide was the first Australian city to have a complete system of tram cars[61]. An Act authorising the establishment of horse tramways was passed on 22 December 1876 and most suburbs soon had a service[62]. The Municipal Tramways Trust (MTT) was formed in 1907 to buy out the seven suburban horse tramways and "electrify" the lines. The first section opened on 9 March 1909; the conversion was completed by 1914. The first tramcar bodies were built by local firm Duncan & Fraser[63].

The MTT built three converter stations to supply DC to the tram network including one on East Terrace (see Section 7.4). A large workshop and depot (now demolished) and an administrative building were built near the Botanic Gardens; the latter still stands.

In the early 1950s diesel buses were seen as a better transport option. Post-war petrol rationing had ended and bus routes could be extended without massive capital expenditure on tracks and overhead power lines. The power house closed on 29 June 1956 and the last street tram ran from Cheltenham to the City on 22 November 1958[64]. Only the tram to Glenelg (which has its own separate right-of-way) was left[65].

The Adelaide to Glenelg tram service commenced on 14 December 1929, replacing the train service which began on 4 August 1873[66]. The line was extended through the city to North Terrace in 2007 and is now operated with "Flexity Classic" trams made in Germany.

8.4 *Buses*

The first City service was begun by a private operator with one motor bus on 17 December 1914. On 25 March 1925 the MTT began its own bus service but with fuel engines rather than electric traction. On 7 November 1928 the MTT was given the exclusive right to carry passengers by "motor omnibus" in the metropolitan area[67].

Unique to Adelaide is the O-bahn bus service, the world's longest and fastest guided busway which runs north-east of the City. The concept was developed by Daimler-Benz and introduced in 1986. Special buses equipped with guide wheels connected directly to the steering system leave the streets at North Adelaide and travel at speeds of up to 100 km/h on the elevated 12 km long concrete track.

9. BRIDGING THE TORRENS

Successfully bridging the river was to prove a significant engineering challenge which would take nearly 14 years to master (from 1839 to 1853).

9.1 The First Bridges

In May 1839 work commenced on a "strong and temporary" bridge under the supervision of Alfred Hardy, the Town Surveyor. Flood damage was repaired in 1843 but the following year it was carried away. The location is marked by a cairn on the southern bank.

9.2 The City/Adelaide Bridge

A timber-decked bridge supported by iron bow-string girders carried on masonry abutments was opened in October 1856 and named the City Bridge. But within twenty years its roadway was proving inadequate for traffic.

In 1874 the City Council decided that a new City Bridge was needed. It was renamed the Adelaide Bridge when it opened on 25 April 1877. In August 1920 the City Engineer prepared plans for a new bridge but the work was deferred for several years. Finally, the new concrete arch bridge was officially opened on 5 March 1931[68].

9.3 The Frome Bridge and University Footbridge

The Frome bridge opened on 18 August 1842. It was damaged by floods and finally destroyed in 1855. A ford and then a footbridge replaced it until the Albert Bridge opened[69].

The idea of a footbridge connecting the University of Adelaide with its playing fields north of the river was put forward by a civil engineering undergraduate in 1928. The bridge was designed by the South Australian Railways and opened on 9 August 1937. It was the first welded steel bridge built in South Australia and consists of two balanced cantilever sections joined by lateral shear locks at the apex of the arch[70].

9.4 The Hackney Bridges

The river crossing at Hackney was an important one because it gave wheat growers on the Adelaide Plains direct access to the SA Company's flour mill (see Section 5.1).

The first bridge was a simple timber structure built about 1845 which managed to survive six years of floods until 24 September 1851. Traffic then went back to using the ford or had to detour downstream to the Frome Bridge. A contract was let for a new bridge on 17 October 1853 and it opened on 8 May 1855. The deck was carried by timber trussed girders fixed by iron-plated joints. However, the timber structure required constant repairs and finally succumbed to termite attack. The bridge was declared unsafe and closed towards the end of 1883[71]. (The banks were also damaged by scouring to the extent that the mill itself closed and had to be demolished in 1875.)

A new bridge was designed with seven wrought iron arch truss ribs, the first bridge in South Australia to use this form. The abutments were made of concrete and faced with masonry; it may have been one of the first projects to use locally-produced Portland cement (a plant had opened at Brighton on 12 December 1882[72]). The bridge was opened on 5 December 1885 and still carries south-bound traffic today. The timber deck was replaced with reinforced concrete in 1937-38 and a new bridge carrying north-bound traffic was completed on the downstream side in 1968[73].

9.5 The Victoria and Morphett Street Bridges

The Victoria Bridge was opened on 21 June 1871. However, to use it the citizens first had to cross the railway line. A level crossing was provided in 1860 but public protest led to the construction of the Overway Bridge in 1868. Twelve years later it was demolished and the level crossing was reinstated. In 1884, a lattice girder bridge was built across the railyards.

In 1964, the City Council decided to replace both bridges and realign the Morphett Street exit to North Adelaide. A contract was awarded in May 1966 and the present twin bridges (crossing the railyards and the river) were completed in May 1969. They are prestressed concrete trapezoidal box girder structures[74].

9.6 The Albert Bridge

When the old City Bridge was replaced, the City Council stored the old bow string structure with a view to re-erecting it. However, it proved cheaper to build a new one and a design competition was held. The winning design by John Grainger and Henry Worsley had wrought-iron girders resting on cast-iron piers filled with concrete; it remains an attractive structure across the river, despite the awkward bends in the approach road. Iron work was ordered from England but it was fabricated and erected under the local supervision of the City Surveyor James Langdon. The bridge was opened on 7 May 1879[75]. The timber deck was replaced with concrete in 1933-34 and that deck was reconstructed in 1982. A refurbishment in 2001 added traffic safety barriers and won Connell Wagner an Engineering Excellence Award.

10. COMMUNICATION

10.1 Telegraphy

When the Government decided it needed to have a telegraph line linking Adelaide with its port, Charles Todd was chosen for the task. He arrived in Adelaide on 5 November 1855 with his assistant Edward Cracknell and built a double circuit line which opened for general traffic on 18 February 1856[76].

10.2 The Intercolonial Telegraph

Todd's next step was to establish communication with Victoria. A 320 mile line connecting Mount Gambier with Portland in western Victoria was opened on Wednesday 21 July 1858[77]. Three months later, a line connected Sydney with Albury on the NSW-Victorian border and from 9 October 1859 Adelaide was in direct communication with both Melbourne and Sydney. A direct link to Sydney was not built until May 1867[78]

10.3 The Overland Telegraph

As telegraph lines crept steadily eastwards through the sub-continent and Asia, communication with England and Europe became a growing possibility and the South Australian Government made a bold decision to build a line to connect with the overseas cable. Charles Todd was given the formidable challenge of building the 1200 mile line in just 18 months. The first pole was planted at Port Darwin on 15 September 1870[79]. The overseas cable was ready for service on 20 November 1871 – unfortunately the Overland Telegraph line wasn't. It was finally joined on 22 August 1872. In the meantime, the undersea cable had failed and wasn't back in service until 21 October. The first message from overseas was received at the Adelaide GPO on 22 October[80]. An Historic Engineering Marker was placed at the GPO on 22 October 1999.

10.4 Electra House

The Eastern Extension Australasian and China Telegraph Company controlled the overseas cable. In 1921 the company acquired a building in King William Street which they named Electra House in 1940[81]. As radio transmission took the place of cable, the need for the station declined and it closed on 15 January 1949[82].

10.5 Telephones

The first South Australian experiments in telephony were carried out by Adelaide brassfounder A W Dobbie[83]. The Postmaster General's Department (PMG) in Adelaide began trials of telephone equipment in January 1878. These were the first official telephone experiments to be conducted in Australia[84].

A number of private lines, most of them connecting the City with its port, were erected in 1882 but the telephone exchange in the north-west corner of the telegraph room in the GPO didn't open until 14 May 1883; there were 48 subscribers[85].

A three-storey building to house the central telephone exchange was erected in 1908[86]. The exchange closed on 13 May 1955.

10.6 Wireless

On 21 September 1897 Professor (later Sir William) Bragg gave the first public demonstration in Australia of wireless telegraphy[87]. The State Government asked Charles Todd to investigate and on 10 May 1899 Bragg and Todd were able to establish communication over a distance of about 200 yards. Although their experiments were well ahead of work being done in the other States, the cost was still too great for a system to be installed and the project was abandoned in February 1900[88].

About 1922, people began exploring the possibilities of broadcasting as a form of entertainment[89]. Several radio stations were established and Adelaide's tall buildings were popular choices for studios; many had transmissions masts on their rooftops.

11. MANUFACTURING

In the 19th century, Adelaide was literally a hive of industry with all manner of manufacturing taking place within its square mile. Fortunately for today's citizens, it was all shifted to more appropriate locations long ago and the streets give no clue to the foundries and factories and sawmills that once gave employment to thousands.

11.1 Foundries

Significant in the early engineering history of Adelaide are the pioneer foundrymen John Wyatt and William Pybus. John Wyatt arrived in the Colony on 22 April 1837 and, by 1841, had established an engineering business. A few years later he built a foundry in Grenfell Street called the Adelaide Foundry. In 1847 he moved the foundry and workshops to large premises on North Terrace at the corner of Victoria Street. His sons George and Joseph Henry took over the business in 1847. Following the death of the brothers, the foundry was sold to A Jones & Sons in 1878[90].

Table 11.1: Adelaide City Foundries[91]

Foundry	Location	TA	Years
Wyatt/Adelaide	Grenfell St	--	1843 - 1847
Wyatt/Adelaide	North Tce	11	1847 – 1878*
Pybus/Victoria	Hindley St	76/111	1842 - 1848
Pybus/Victoria	Hindley St	60	1848 - 1915
Pappin & Jones	Blyth St	13/50	1855 - 1867
A Jones & Sons	Blyth St	13/50	1867 – 1878
A Jones & Sons	Union Lane	11	1878 – 1912
A W Dobbie	Gawler Pl	81	1862 – 1914
A W Dobbie	Pirie St	--	1914 – 1931
Hooker	Hindley St	--	1875 – 1883
Strapps	Currie St	131	1863 - 1944
Forwood Down	Hindley St	69	1873 – 1955
Union	Blyth St	--	1882 – 1907
Union	Morphett St	54	1907 – 1915
Sun	North Tce	3	1886 – 1896
Stewart & Harley	Hindley St	68	1896 - 1909
Harley/Sun	Hindley St	68	1909 – 1926
Cornwall	Hindley St	--	1898 - 1913

* Then sold to Jones & Sons

William Pybus established a foundry around 1842 and was possibly the first in Adelaide to do so[92]. He was also a partner in establishing Adelaide's water supply (see Section 4.1). Many of the other major foundries were established in the City itself and are listed in Table 11.1.

Many of these foundries have left their mark on Adelaide, their names being found on various gates, pillars, etc. The Sun Foundry, in particular, produced a wide range of products including much of Adelaide's distinctive cast iron lace work. Alan Harley joined founder Colin Stewart in 1887 and bought out the partnership in 1909[93]. Fulton & Co, founded by George Fulton and Robert Lungley in 1879, had an office in the City but their foundry was in the suburb of Goodwood[94].

11.2 Automobile Manufacture

Until quite recently, Adelaide was home to not one but two major automobile manufacturers - General Motors-Holden and Mitsubishi Motors Australia; both had their origins in coach building and saddlery. J A Holden & Co was established in 1856 and built their first motor bodies in 1914. Four years later they formed a separate division, Holden Motor Body Builders, and built a large factory in King William Street. The General Motors Corporation bought the business in 1931 and merged it with General Motors Australia to form General Motors Holden[95]. Duncan & Fraser had a similar story, building custom bodies for Ford (as well as tram bodies – see Section 8.3); in 1930 they were taken over by T J Richards, another local business, which had been building Chrysler bodies since 1928. Richards, in turn, was taken over by Chrysler Australia which was then purchased by Mitsubishi Motors in 1980.

Tom O'Grady, foreman of the Lewis Cycle Works, built a small gasoline engine and fitted it to one of their pacing triplets. It was seen on the streets of Adelaide early in 1899[96]. The following year they began to build a motor car in their workshops off Gawler Place[97] and went on to produce at least eight more[98]. Other vehicles were made in local workshops, most of them cycle manufacturers but at least two were made by James Henry Southcott. Southcott was a precision machinist who founded his Gilles Street business in 1886.

12. PUBLIC HEALTH

12.1 Sewers and Drainage

In the 1870s, Adelaide's death rate was nearly double that of rural areas[99]. An Act was passed in 1879 and main sewers were constructed. A Sewage Farm was established north of the City and, from 7 January 1881, Adelaide became the first Australian capital city to provide a separate water-borne system[100]. The Farm continued to operate until 1964 when the first stage of a new treatment plant opened at Bolivar.

12.2 Rubbish Collection and Disposal

At first rubbish was dumped in the Parklands in pits left by the removal of limestone for building. A destructor station or incinerator was discussed as early as 1894. Heenan & Froude Ltd of Manchester installed a three cell, two unit refuse destructor; rubbish was first processed on 20 June in what was effectively a recycling station – even the soot from the chimney was collected and used as top-dressing on the parklands gardens! The station closed in 1954 and everything but the chimney and a few small outbuildings was demolished in 1997.

13. RECREATION

With all the basic needs finally catered for and local industries up and running, the citizens could finally turn their minds to enjoying themselves and the centrepiece of their recreation was to be the River Torrens. It is fitting, then that this story of Adelaide's engineering heritage should start and finish with its river.

13.1 The Botanic Gardens

Adelaide's Botanic Gardens were established on their present site in 1854. Director Dr Richard Shomburgk wanted to start a collection of palms and ordered a special glass house. Designed by Gustav Runge in Bremen, Germany, the Glass House was transported to South Australia in kit form and then assembled on site. It opened in 1877. Its hanging glass walls are similar to those used in modern city buildings. The design was very advanced for its time and is the only structure of its kind in the world today.

It was closed in 1986 because corrosion of the iron glazing bars made it unsafe for public use. A full restoration commenced in 1992 and it now only displays plants which require warm and dry conditions to preserve its wrought iron structure.

13.2 Torrens Lake and Elder Park

The first attempt to create an ornamental lake was in October 1867 when the Sheriff of the Adelaide Goal used prison labour to build a wooden dam. It was washed away almost immediately.

Construction of a simple concrete weir began in November 1880; this was one of the first uses of concrete in a civil engineering project in Australia. Mayor Edwin Smith closed the sluice gates for the first time on 1 July 1881. In 1889, the first serious flood overwhelmed the new weir and jammed its gates with debris. In 1917, the City Engineer, prepared plans to replace the centre section of the weir with two flood gates and the rebuilt weir was reopened in May 1929.

14. THE BOOKLET PROJECT

Sadly, for technophiles, all this activity has left little sign of its presence in today's City. What was finally chosen for the guide booklet was based on three requirements:

1. Was there something left to see?
2. Did it help tell the story of the City?
3. Was it unusual or amusing?

As the research progressed, we were able to increase the original list of 17 items to more than 70. However, they literally stretched from one end of the city to the other and this is where the Adelaide City Council's Connector

Bus makes a happy contribution – it circulates through the City and effectively connects all the places that people might want to visit.

15. ACKNOWLEDGMENTS

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A particular debt of gratitude is owed to Geoffrey Manning who painstakingly ploughed through 100 years of Adelaide newspapers and created an index to their contents at <http://www.slsa.sa.gov.au/manning/>.

16. REFERENCES

Note re Units of Measurement:
The units originally published are used throughout. There are plenty of sources available to convert British or Imperial units to the CGS system.

(see next page)

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Waitaki Dam – 75 Years On

Ian G Walsh – FIPENZ, MNZSOLD, MNZSEE, MNZGS, MNZSfRM

SUMMARY: *The Waitaki Dam situated on the lower Waitaki River on the east coast of New Zealand's South Island was constructed between 1928 and 1934, a period influenced by the effects of the great depression. The overspill concrete gravity structure is historically significant in several technical respects. This was the first hydro-electric generation scheme developed on a major South Island waterway, and aspects of the design and construction presented challenges that were new to New Zealand engineers. International design review during construction identified shortcomings in the understanding of uplift pressures on the stability of the dam blocks, resulting in an additional drainage gallery being retrofitted to the heel of the dam outside of the upstream face. Closure of the diversion sluices presented a major difficulty as three gates overshot their seat and were unable to be raised back into position under the pressure of the rising lake. An innovative sealing detail was developed, but the bitumen used at the time to grout the final opening has been subject to extrusion over the years. Adequate stability of the dam blocks under uplift and extreme loading including earthquake events has been an ongoing matter of investigation and analysis over the life of the dam as engineering knowledge has progressed. In 1961 a major anchoring project was completed, where the dam blocks were secured to the foundation by 300 ton capacity stressed and grouted cable anchors. Predicting the reliability of the long term performance of these fully grouted anchors has presented difficulties, and further uplift control improvements were completed in the early 1990's to improve confidence in the performance of the dam.*

1. GENERAL

The Waitaki Hydro Electric Power Station is located on the Waitaki River in the South Island of New Zealand, 6km upstream from the township of Kurow (Figure 1).

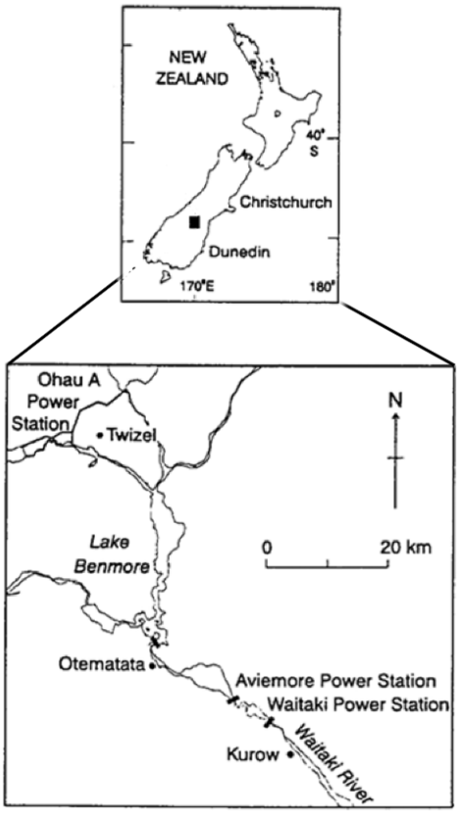

Figure 1. *Location*

It is currently the last in a cascade of power stations owned by Meridian Energy Ltd that utilise the 342 cumec mean flow of the Waitaki River that originates from Lakes Tekapo, Pukaki, and Ohau and flows to the East Coast between Dunedin and Christchurch.

This was the first hydro scheme developed on the river, and in fact the first constructed on a major river in the South Island by the then Public Works Department. This year (2009) will see the achievement of 75 years of successful operation of the power station, and the supply of valuable energy to the people of New Zealand.

However, the success has not been without its challenges and difficulties (Anderson 1937) as engineering knowledge and experience regarding such significant civil engineering undertakings has been gained over the years (Ridley 1954). Design knowledge in New Zealand in the 1920's and 1930's was not particularly advanced in this type of development, and several non-conservative aspects of the original design have lead to progressive reassessment and modification to the dam from the time of construction up to the present day

As a depression era project constructed with much manual labour input over the period 1928 to 1934, the dam has a special place in the social changes that occurred at that time leading to the introduction of the social security system to protect workers against the effects of unemployment (Natusch 1984).

This site has significant value in terms of our engineering heritage, as it contains visible evidence of our increasing ability to tackle major infrastructure works in a time when manual labour was still a key element in the construction process. In this paper I have focussed on the civil engineering aspects with a bias towards dam safety management, as this is my particular area of activity.

2. DESCRIPTION

The dam site was originally referred to as "Awakino" after the locality, but as the first "dam on the Waitaki River", the work came to be called simply the Waitaki Dam, despite the official expectation of further future development on the river. The site was chosen in 1927 for its topographic and geological setting. The ability to construct the large powerhouse on the southern bank (true right) clear of the main river channel, and the presence of good foundation conditions in the form of greywacke rock under a shallow cover of alluvial gravel suitable for concrete production were key factors in the selection. The existence of the Dryburgh fault in the vicinity was known, but seismic considerations generally were not initially thought to be significant in this area.

***Figure 2**. View of Site from the North Bank c2002*

The major components of the current site comprise a 354m long 36.5m maximum height concrete gravity dam, which also acts as an overflow spillway (Figure 2), together with a 105MW capacity powerhouse on the south bank housing 7 machines utilising an operating head of ≈21m. The curved layout of the overspill dam was built to suit the discharge flow direction into the river channel, and is not designed to act as an arch dam. The radius of the curve is 609.6m on the true right, and 228.6m on the true left, with straight sections at the power house and abutments.

The 150m long reinforced concrete power house is an impressive structure in its own right. The two machines initially commissioned in 1934 are shown in the background in Figure 3. The original power house was constructed to accommodate five machines which were progressively installed, and the power house was extended into the right abutment in the period 1948 to 1954 to accommodate a further two machines.

***Figure 3**. View inside Power House c2003*

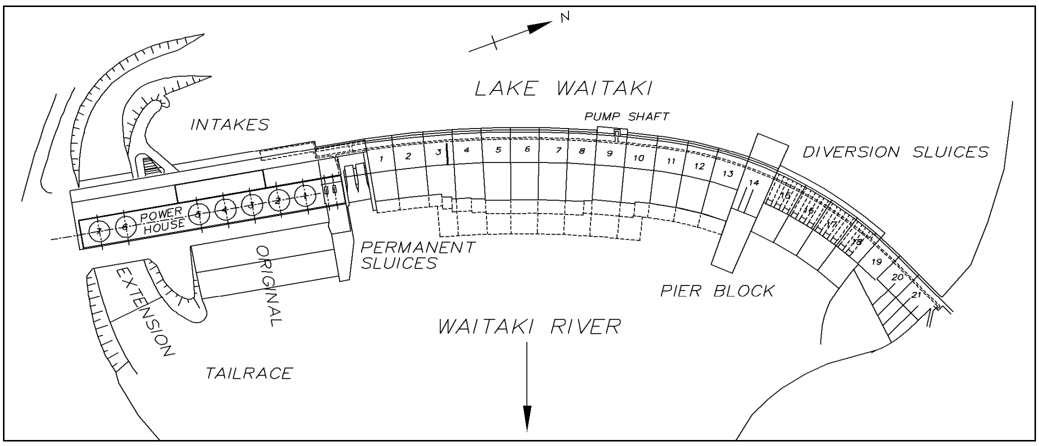

***Figure 4**. Site Layout Plan*

The 21 dam blocks are typically some 16m wide forming an uncontrolled ogee type spillway to carry the design flood from the 9735 km^2 catchment.

The block joints are sealed with oxidised bitumen of 40/50 penetration grade placed after completion of the concrete placing and curing in formed continuous pockets at the contraction joints. Construction diversion was achieved through a series of eleven 3.7m high by 3m wide temporary sluices on the northern end of the dam adjacent to the true left abutment which were subsequently infilled; not totally successfully in all cases as is discussed later.

Galleries are present at three levels within the dam; the uppermost air gallery which provides an air supply to the aeration vents on the spillway face, the middle gallery, and the lower Hornell gallery at foundation level outside the heel of the dam. This latter feature is unusual and has an interesting history that is discussed later. Internal drainage is by pumping from a central pump shaft on the upstream face, although originally a venturi piping system was installed. There is some question as to the effectiveness with which this device might ever have functioned, but it was never commissioned to test the original design concept. Original foundation drainage was provided by porous "no-fines" concrete drains placed on the prepared rock foundation, but subsequent stability considerations resulted in relief drains being drilled during the 1950's and in the period 1960 to 1961 a series of 200 and 300 tonne capacity anchor cables was placed, grouted and stressed in holes drilled from the dam crest into the foundations. These cables were subsequently fully grouted, preventing any further proof testing of their condition.

The main features described are shown in Figure 5 below.

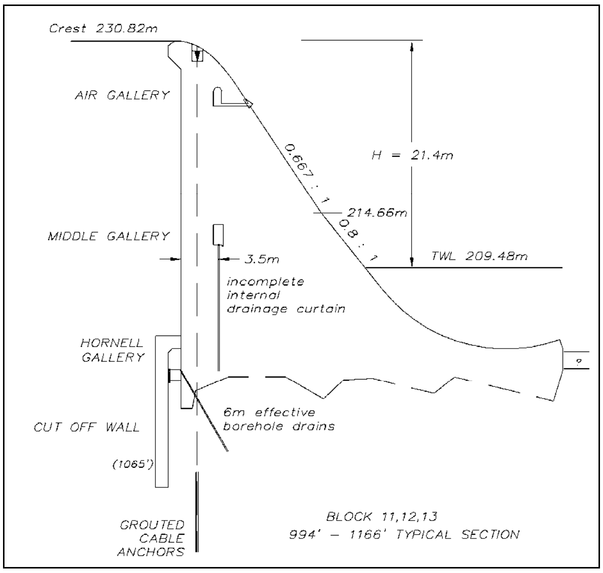

***Figure 5**. Typical Cross Section*

The typical cross section shows the change in slope of the dam face from 0.667H:1V to 0.80H:1V which applied to later dam blocks after the non-conservative nature of the original design was identified.

3. CONSTRUCTION METHOD

Construction of the power house situated on the south bank of the river away from the main river channel was able to be commenced early to give time for the generation plant to be installed while the dam wall progressed across the river channel in conditions exposed to flood hazards. River diversion and dewatering for construction were major considerations for this project as the first development of its type in the South Island. Block 14 was designed as a temporary pier constructed with sheet piling providing a secure temporary abutment for the Canterbury (north bank) and Otago (south bank) coffer dams. The following images illustrate progressive nature of the construction as diversion was achieved and construction of the blocks completed.

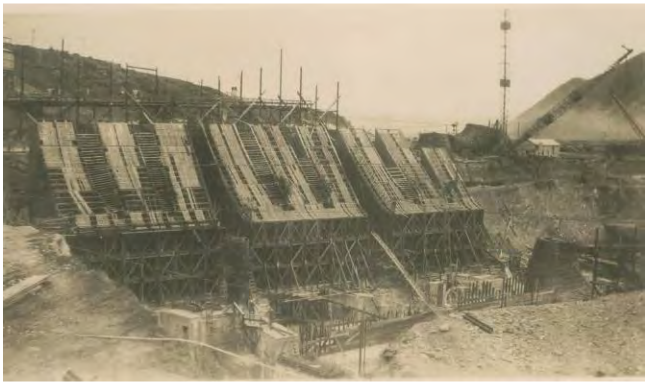

***Figure 6**. Power House Foundation Construction and Concrete Intakes and Penstocks c1930-31*

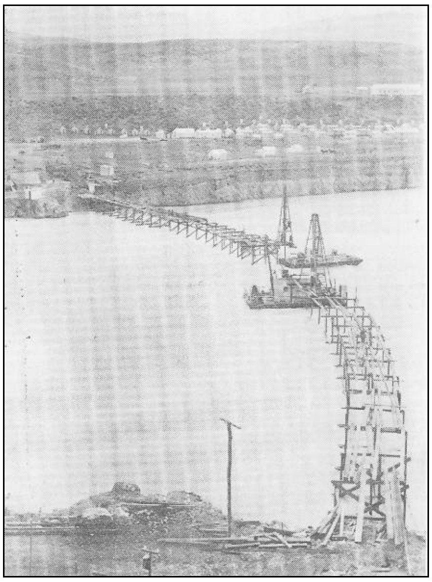

***Figure 7**. First trestle bridge cDec 1928. Damaged by a flood in Jan 1929*

Figure 8*. View of Block 14 Pier, Canterbury coffer dam sheet piling and earthworks constructed off the trestle bridge c1930*

Figure 9*. View from further downstream showing barge*

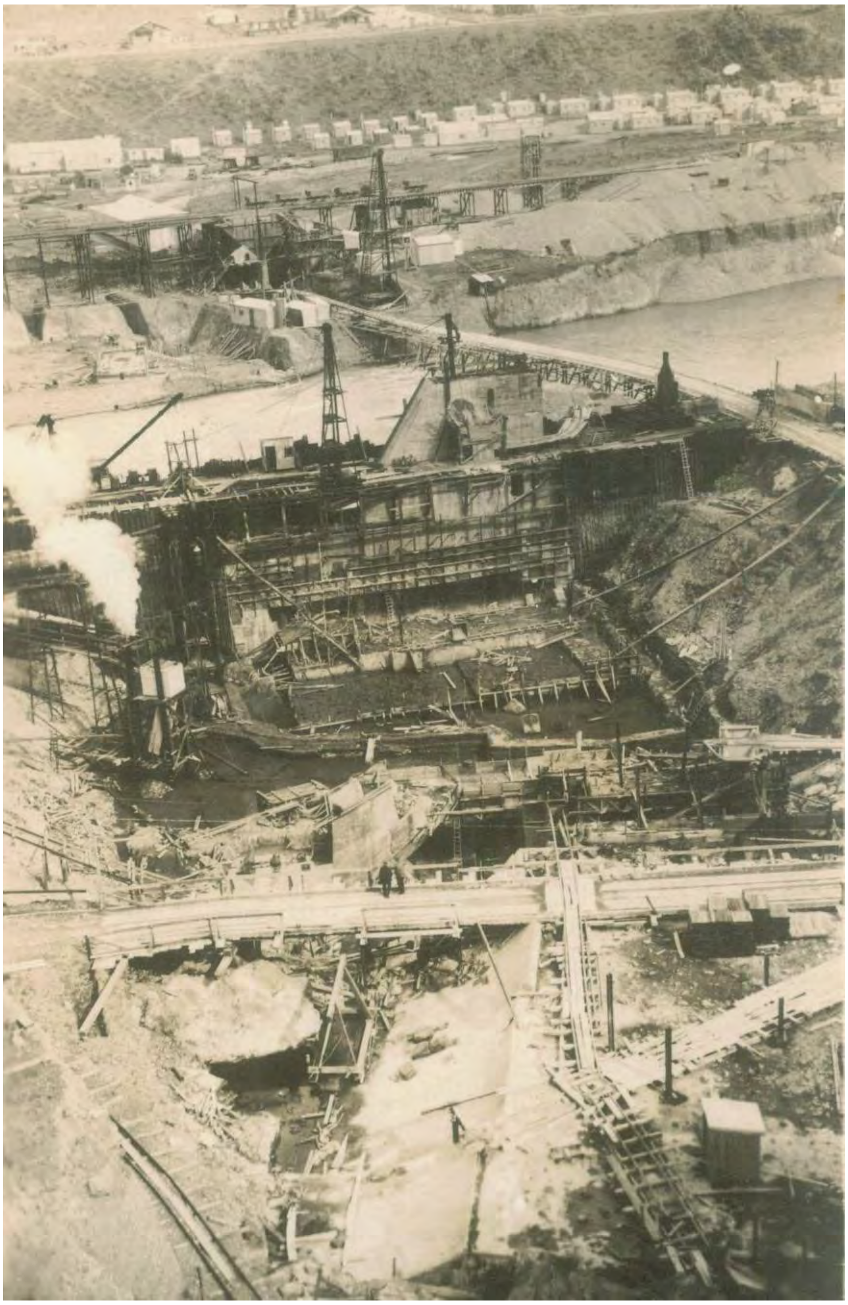

***Figure 10**. Dewatered Canterbury foundations under proposed diversion sluice blocks*

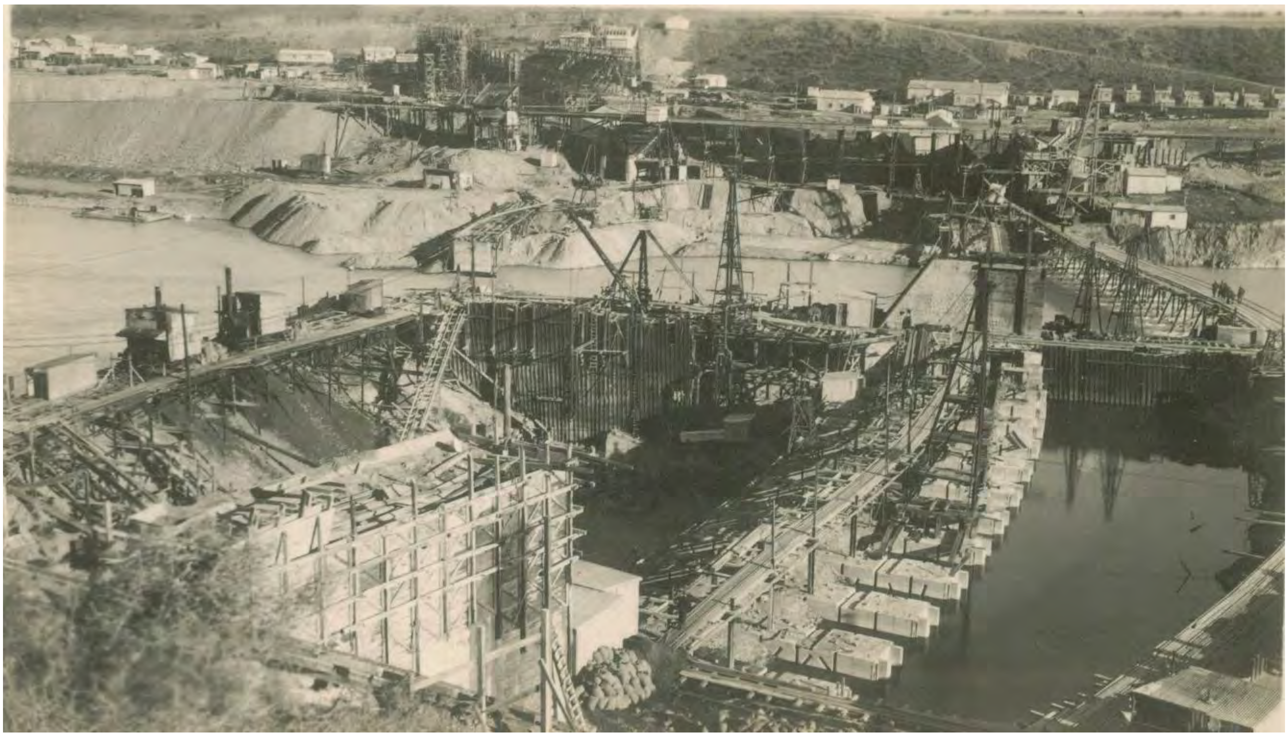

Figure 11. *Diversion sluices well advanced. Aggregate recovery progressing. Power house falsework in background*

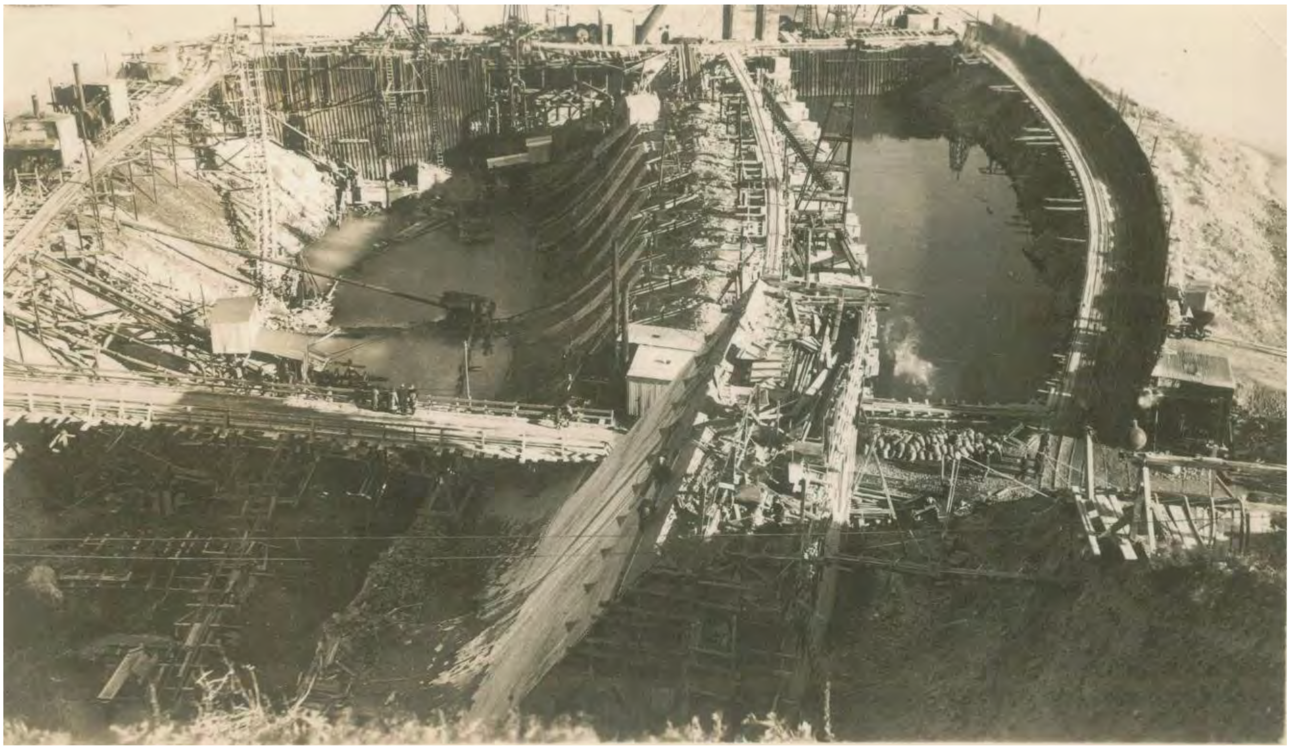

Figure 12. *View from Canterbury abutment; blocks progressing adjacent to diversion sluices*

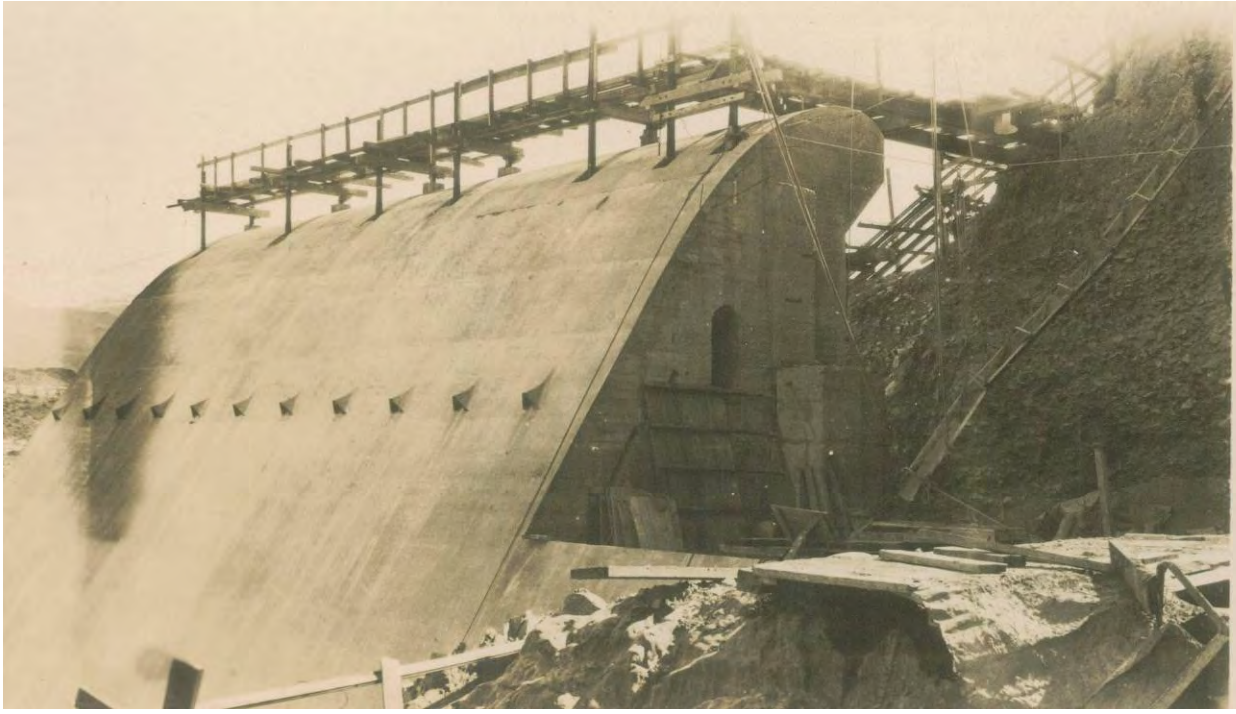

***Figure 13**. Left abutment block 21 showing ogee parabolic crest, air gallery and aeration ports. Excavation through surficial gravel to expose rock foundation also shown in this view.*

***Figure 14**. View from Otago bank, block shear keys shown.*

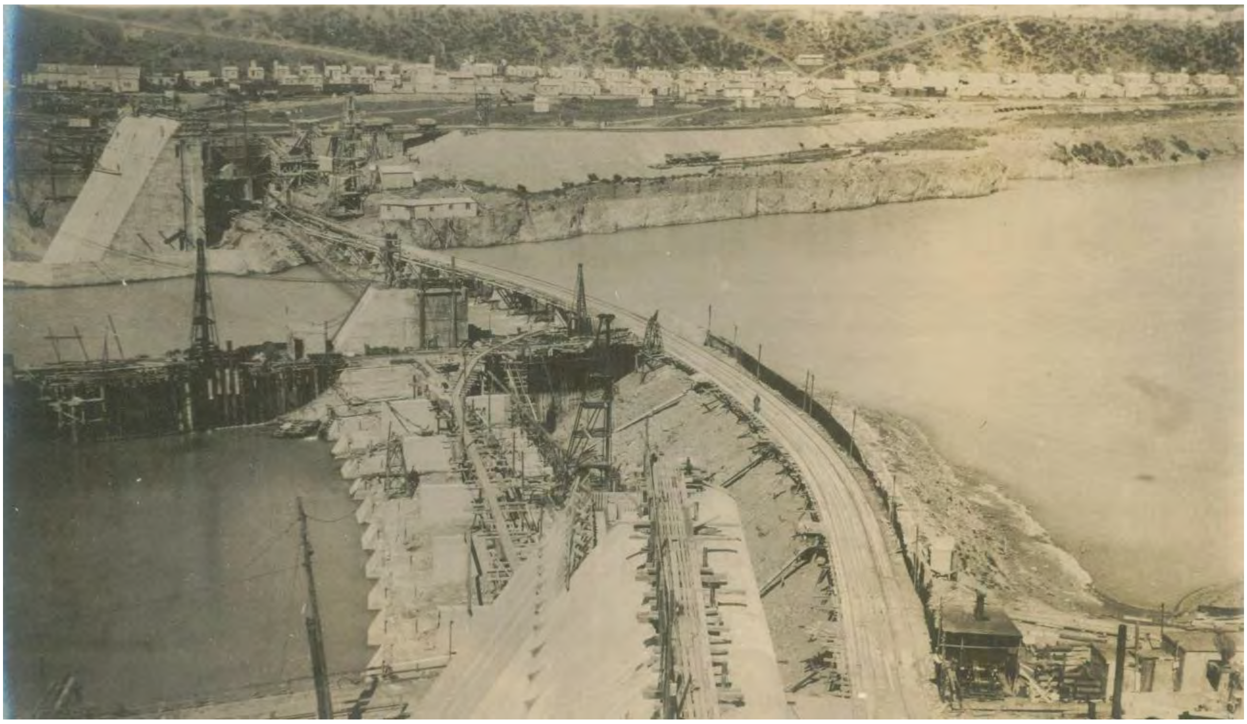

Figure 15. *View from Canterbury bank at similar stage*

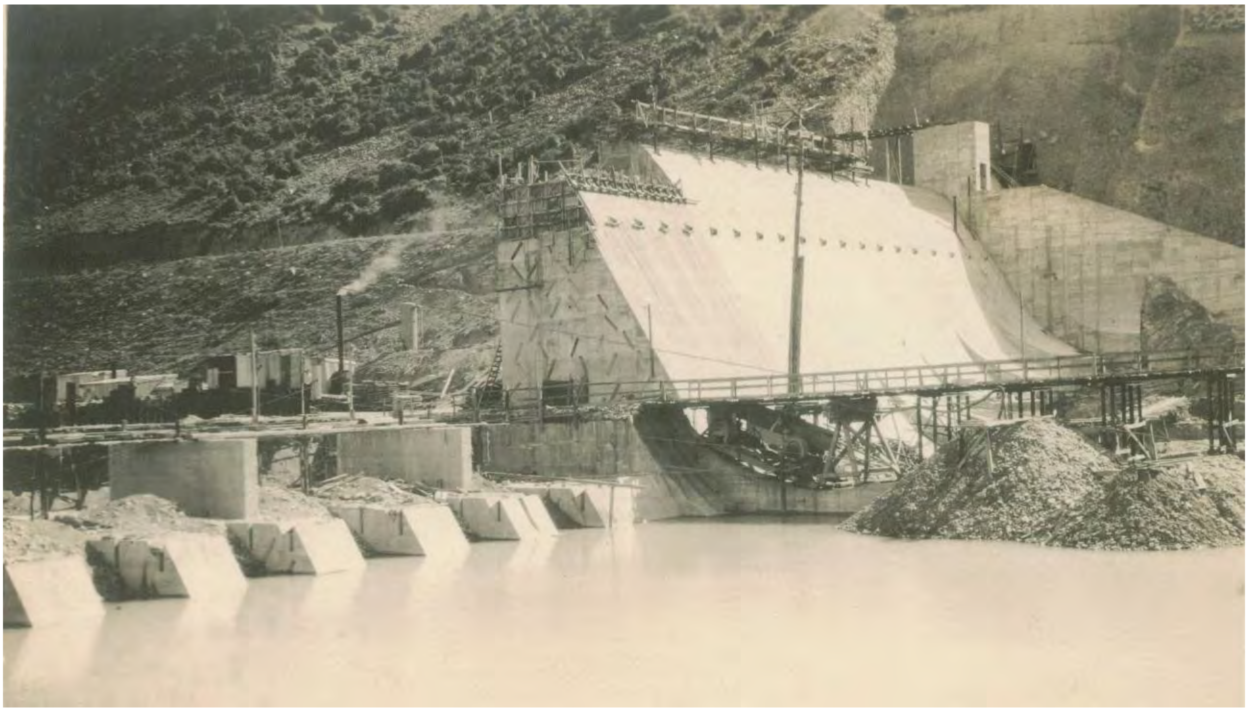

Figure 16. *Canterbury abutment wing wall completed*

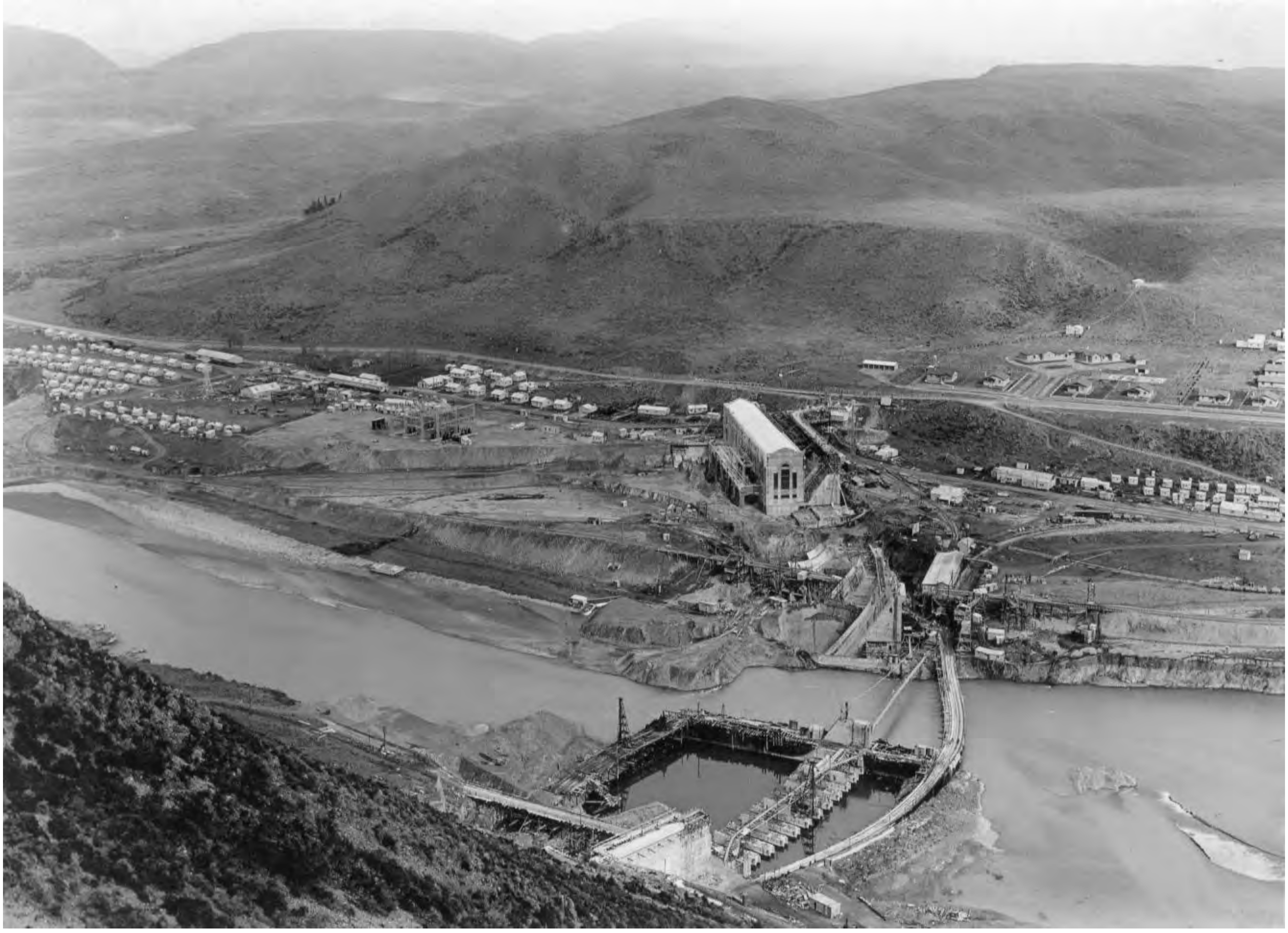

Figure 17. *Overall site view from Canterbury abutment before diversion. Switchyard progressing on far bank.*

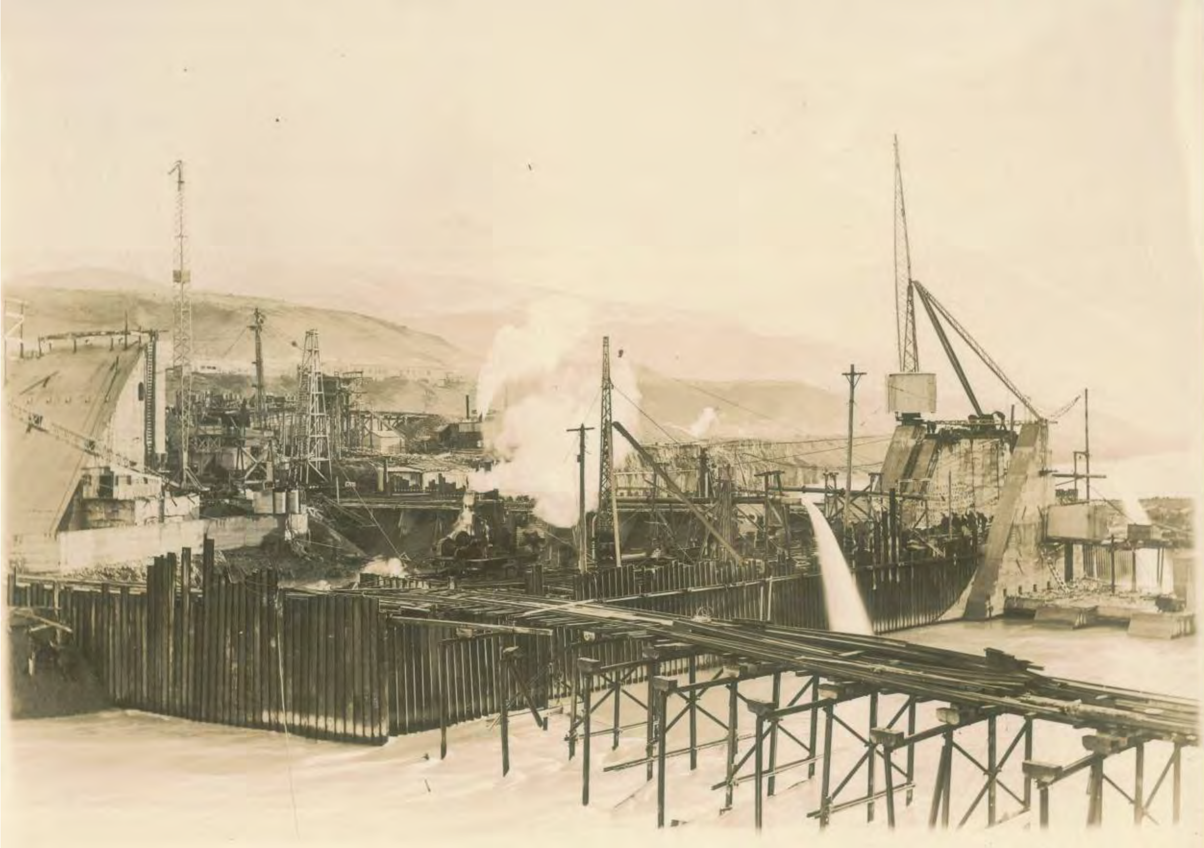

Figure 18. *Dewatering Otago coffer dam area showing sheet piling and pumps*

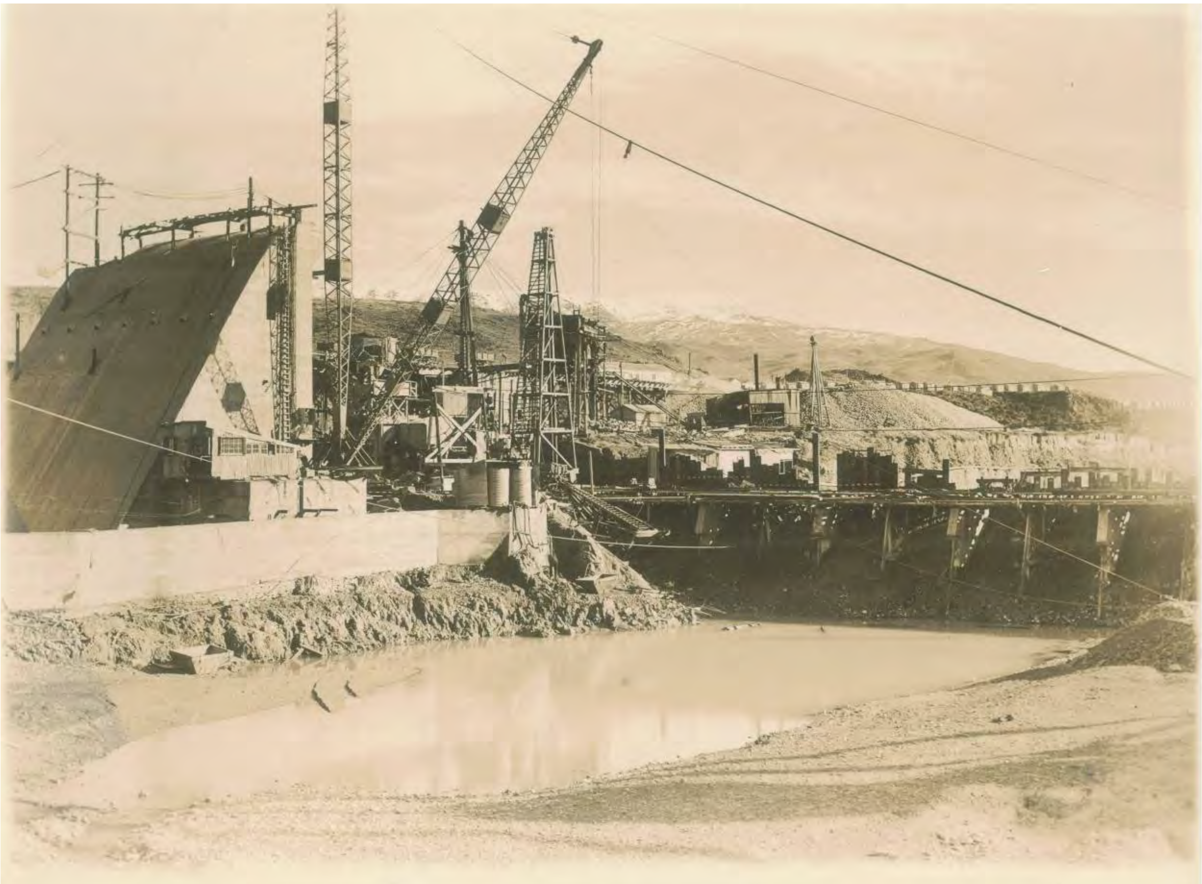

Figure 19. *Dewatered Otago river channel*

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Figure 20. *Initial dam blocks well advanced.*

Figure 21. *Closer view of initial Otago Blocks and substantially completed Power House structure in background. River bank armouring in foreground about to be removed.*

***Figure 22**. Foundation preparation within Otago coffer dam area c1933. Middle gallery and air gallery visible. Light rail tracks were used extensively for spoil removal, and a dragline is visible in the foreground. However, much of the work involved hard physical labour rather than mechanised techniques in this era.*

***Figure 23**. Diversion operating*

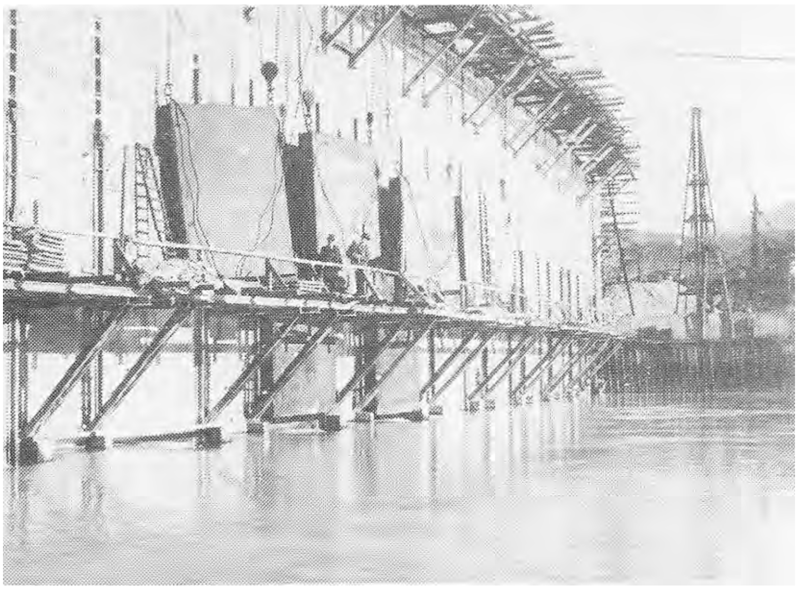

***Figure 24**. Completion of concreting over the diversion sluices and placing the bulkheads c 1934. The supports to the last three bulkhead gates placed after this photo was taken structurally failed when being placed during high headpond level, resulting in the bulkheads overshooting their seating and not sealing as intended. This situation did not stop the filling of the lake nor the planned official opening.*

***Figure 25**. Official opening 27 Oct 1934*

The very large power house by today's standards for a 75MW station was needed to accommodate the large diameter machines that were designed to have very high rotational inertia to limit the risk of surge induced overspeed problems related to the small capacity of the receiving grid in those days. The station operated for a short time on 1/3 power output at 66kV rather than the intended 110kV until the remote grid transformers were upgraded.

The three leaking sluices still remained to be stopped, so efforts were made to seal the bulkhead openings with whatever could be sourced to plug the gap to enable permanent concrete infill to be placed. These efforts were not successful, and eventually a novel means of stemming the flow was devised using "the mouse-trap". Pipe sections fitted with a cut off valve were fabricated to insert into the leaking sluices from the downstream end. These pipes could carry the leakage flow in a controlled manner allowing the zone outside the pipe wall to be filled with concrete. Upon closing the valve on the pipe the inner zone could also be sealed in static conditions. However the mouse-trap proved to be prone to jamming in the tight fitting sluiceway, and the final solution involved a man being manoeuvred up the sluice in a "submarine" to attach a pulley block at the upstream end to then enable the mouse-trap to be drawn into position.

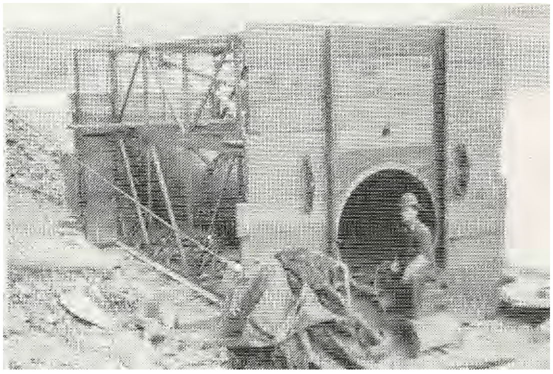

***Figure 26**. The "mouse-trap" being readied for use in sealing the leaking sluices*

***Figure 27**. The completed scheme including the original weir and pool fish ladder visible at the end of the power house.*

The fish pass proved to be ineffective with no fish ever being observed to traverse its full height. The pools were thought to be too small and the gradient too steep for the fish. The 1950's power house extension was built over this area.

4. DISCUSSION ON ASPECTS OF DESIGN

The concrete dam has a full and interesting history, including design modifications during construction and shortly thereafter to reduce the destabilising effects of uplift pressures, the installation of stressed cable anchors in the early 1960s, and refurbishment of foundation drainage in the 1990s (Walsh, 1994). The presence of a major fault zone (Dryburgh Fault) in the river channel beneath the dam comprising weak closely jointed argillite rock has presented its own challenges in terms of current seismic resistance expectations, although the gentle arc of the dam layout originally adopted has been advantageous in providing some potential for additional displacement resistance. Most recently the long term performance of the original bitumen water stop seals between the dam blocks has been investigated to assess their remaining life as the bitumen is gradually displaced by seasonal thermal contractions and sustained water pressure.

4.1 Pore Pressure Uplift

The initial design of the dam at Waitaki has proven to be non-conservative, particularly in the consideration and treatment of uplift pressure as it affects the stability of the blocks (Anderson 1937). The original design with its 0.667H:1V face slope made inadequate provision for water entering joints or defects in the concrete or the foundation and generating hydraulic uplift forces, as New Zealand engineers of the time did not recognise the full significance of this mechanism (Ridley 1954). Although a relief drainage system was initially provided, it did not provide sufficient control of the water pressure to limit the uplift to a value that was adequately countered by the gravity loading of the dam blocks. The Europeans had a more sophisticated approach to this phenomenon at the time, and in 1930 when the construction work was already well underway, Professor P. Hornell from Sweden was consulted in a review capacity to advise on suitable remedial measures. For those blocks still to be constructed, the lower face slope was flattened to 0.8H:1V to increase the effective length and mass of the blocks, (refer Figure 5). An additional gallery (i.e. the Hornell gallery) was retrofitted at the heel of the dam to provide the lowest practical drainage level for the relief drains. Furthermore, a deep cut-off trench was excavated and backfilled with concrete at the heel of the dam to intercept any seepage paths in the shallow foundation.

Despite these improvements, Professor Hornell was still not satisfied with the as constructed design. This view has been affirmed over the years by other dam engineers as various improvements have been undertaken to further address the original shortcomings. Additional internal drainage drilling was undertaken early in the life of the dam, and a major refurbishment of the drainage system was undertaken in the early 1990's.

***Figure 28**. Hornell gallery seal*

By the late 1950's it was decided to offset the limited block mass by the introduction of post tensioned anchor cables installed in holes drilled from the dam crest. Initial plans were for 75 nominal 300 tonne capacity anchors to be used, but in fact a total of 91 anchors were finally installed in 1960-61. The additional anchors were needed to address the high uplift pressures within the poorly infilled diversion sluices, and to lower anchoring shear stress by using reduced post tensioning loads within the poor foundation rock present under blocks 6 to 14 (i.e. Dryburgh Fault). Unfortunately these cables were fully grouted after stressing to protect them from corrosion, so there is now no means of directly confirming their ongoing proof load capacity.

4.2 Spillway

The generously proportioned ungated spillway has proven to be very effective at handling large floods and keeping erosion forces well distributed across the river channel. Operation of the permanent sluices does induce some localised erosion, but there is little need to utilise this facility. Figure 29 below illustrates the flow in a high flow case. The 1998 Probable Maximum Flood Extension Study assessed the PMF discharge to be 7,310m3/s, with a maximum lake level of 234.16m, i.e. a surcharge of 3.34m above crest level. This recent flood discharge assessment is greater than the original design flood expectations for the site, but the assessed surcharge depth is less than the original allowance of some 3.66m. As part of ongoing dam safety assessment work, the dam is currently undergoing a structural safety review to verify performance for current PMF flood loads.

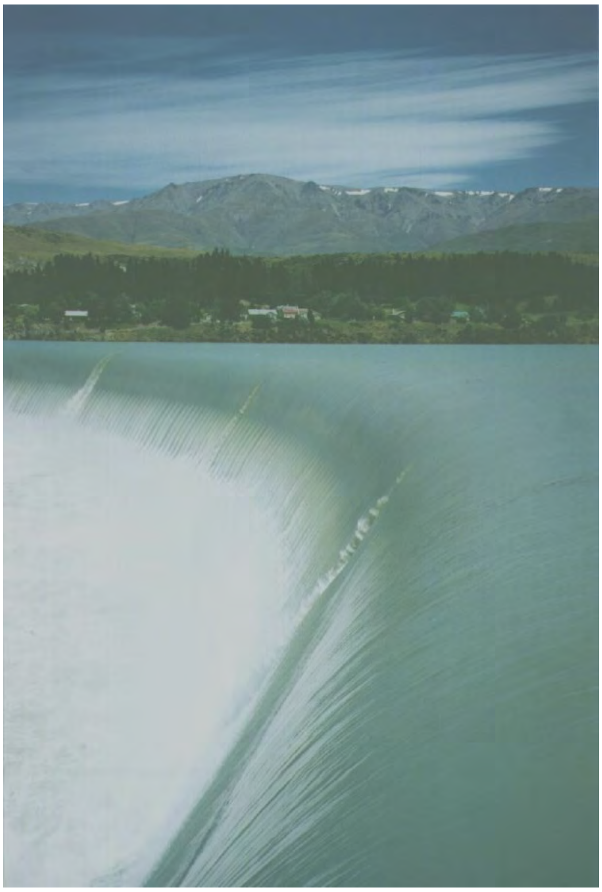

***Figure 29**. Major flood discharge in the 1990's*

4.3 Rock Properties

A comprehensive review of the foundation geology was undertaken to improve the model for analysis

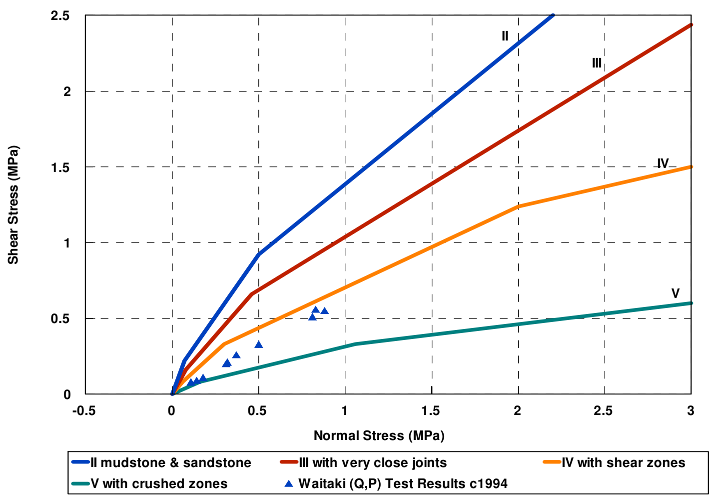

***Figure 30**. Modified Hoek Brown failure criteria*

(Read et al 1994). Foundation rock samples were obtained and some laboratory strength testing was carried out. The mapped rock mass rating ranged from fair (Class I) to extremely poor (Class V).
Figure 30 clearly illustrates the strength reduction that applies to the fractured argillite within the central portion of the dam foundations. Blocks 5 to 15 were assessed to be located on a zone of sheared and crushed Class IV rock associated with the presence of the Dryburgh Fault. Better quality class II rocks, which only contain minor thin sheared seams, are more commonly exposed in the powerhouse and left (Canterbury) abutment areas. The "blue pug", "blue hole" etc., described by the original builders, and the limited shear strength achievable for the central post tensioned cable anchor, are able to be understood in design terms using this current knowledge.

4.4 Seismic Hazards

Our understanding of seismic hazards has changed radically since the 1930's when this dam was designed. While dams have had a good history of performance in earthquakes, the tectonic context of the site has been subject to an ongoing programme of specialist examination by the dam owners over the last 20 years. The most recent assessment (URS 2008) indicates that the Dryburgh Fault passing through the dam site is inactive for dam engineering purposes, i.e. no displacement in at least the last 25,000years. The peak ground acceleration (PGA) for the 1/10,000 annual exceedence probability Safety Evaluation Earthquake (SEE) is assessed to be 0.74g, and the peak horizontal spectral acceleration is assessed to be 2.005g at 0.2 sec and 5% damping. The 1/150 annual exceedence probability serviceability level event, (the Operating Basis Earthquake or OBE), is assed to have a PGA of 0.067g and a peak horizontal spectral acceleration of 0.157g at 0.2 sec and 5% damping.

These loading values differ somewhat from the original perception of an "inactive" seismic environment. As part of ongoing dam safety assessment work, the dam is currently undergoing a structural safety review to verify performance under the currently assessed (SEE).

4.5 Bitumen Water-Stops

The water-stop is a primary component of a concrete dam's water retention barrier. Damage to the water-stop to the extent that it no longer functions effectively can allow high pressure water to enter into the heart of the dam and adversely influence safety and stability. The bitumen used in the joints at Waitaki has shown evidence of extrusion into the galleries over the years, so an understanding of the mechanism is relevant to assessing the life of the seal and any remedial treatment opportunities. 3-axis joint displacement meters are installed across all block joints within the Middle Gallery. These meters were installed to capture any long term trends in block displacement that might be associated with the foundation conditions in the Dryburgh Fault zone within the dam foundation, particularly in a post seismic event situation.

***Figure 30**. Bitumen water-stop extruding into middle gallery*

The monitoring records also reveal the response of the concrete monoliths to seasonal thermal variation that leads to cyclic joint movement. Figure 31 illustrates the "pumping" mechanism (Anderson et.al. 2008) that leads to gradual extrusion of bitumen over the life of the dam under combined water pressure and block thermal cycling on a seasonal basis.

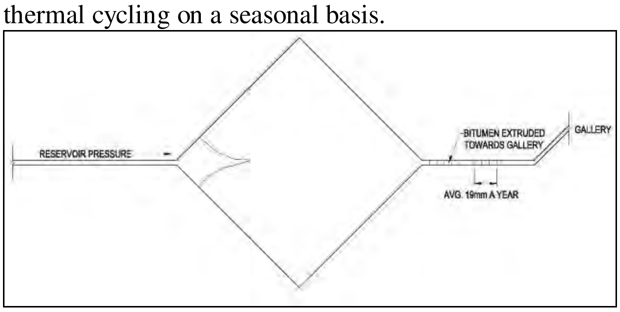

***Figure 31**. Bitumen water stop*

A large quantity of bitumen was also used in the attempts to stem the flow through the leaking diversion bulkheads that failed to seat correctly during first filling in 1934. The viscous properties of the bitumen have allowed this infilling to remain mobile over the years with some displacement via drain / relief holes into the middle gallery as shown in Figure 32 below. In itself this is not a problem, but the resulting cavity left in the sluice ways allows direct coupling of reservoir pressure into the body of the dam blocks, increasing uplift forces.

Figure 32*. Bitumen infill extruding from diversion sluice*

Remedial treatment methods to address these aging mechanisms are currently being considered by the dam owner.

5. CONCLUSIONS

After 75 years of service the Waitaki Dam continues to provide effective service. From its initially dominant position in generation supply, the power station is now a minor contributor to the renewable energy supply that is provided from the total Waitaki River hydro-electric development. However, the Waitaki dam now also plays a very important role in regulating the flows in the lower Waitaki River, allowing the larger Mid-Waitaki Benmore and Aviemore power stations to be operated to support meeting daily peak power demands.

The dam is a key example of predominately manual construction methods used to construct such a significant piece of civil infrastructure. Changes over the life of this asset have been extensive, with increasing design and dam safety management knowledge occurring from the earliest stages of construction right through to the present day. It is testament to the original developers that with effective management the facility has the potential to still provide future generations with ongoing benefits.

Further major refurbishment options for the Waitaki hydro facility have been assessed, to upgrade the generation equipment and facilities for the next 40 to 50 years of generation. The refurbishment option chosen will depend greatly on whether the North bank tunnel project gets the go ahead.

6. ACKNOWLEDGMENTS

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The transformation of Engineering Entrepreneur to Multi-faceted Specialist: From Nation-building as depicted by the career of the Scots-Queensland Sir Thomas McIlwraith (1835-1900) to Global technical participant.

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SUMMARY: *This paper examines the role of the "engineer triumphant" in the Nineteenth Century Imperial context to the professions' explosion in the Twentieth Century. The emergence of the consumer society, nuclear engineering, the military/industrial complexes and the challenges to the monumental "Big Projects" such as the T.U.A., The Three Gorges Dam, the Snowy Mountains Scheme, Aswan High Dam, and the Russian river/steppe experiences will be briefly considered. Finally, the role of the finance-based corporate state, the rise of the Green Movement in the West, together with the challenge of climate change, population growth and short-term political programmes will be mentioned within the context of an expanding but often frustrated profession.*

This paper concerns itself with the careers of Sir Thomas McIlwraith (1835-1900) whose involvement in politics, engineering, pastoralism and finance in Queensland during the second half of the Nineteenth Century can be used as a peg upon which to hang aspects of the great age of imperial engineers. The intent is to briefly discuss the British origins of the engineering profession, its flourishing in Victorian times, the optimism generated by taming nature and man and the calamity of the First World War. Finally the changing nature of the incredibly diverse profession, the rise of technology and managerialism and some challenges as the historian sees the contemporary scene will be discussed. Then, too, Samuel Smiles' celebration of the *Lives of Engineers* and the difficulty, in the Twenty-First Century of similar biographies of the great constructors will be considered. As the great New Zealand biographer of James Cook, J.C. Beaglehole noted:

> We still lack the quantity of intimate description we should like, that analysis of character that with all men, great or little, we feel would somehow make all things plain… he was a man of action and the tendency is to regard a man of action as adequately described by his acts, his biography a succession of things done… But acts are public things and we want to enter the mind. (Beaglehole, J.C., *The Life of Captain James Cook*, London, 1974, p. 698)

McIlwraith was born in Ayr, Scotland, on 13 May 1835 – the son of a manufacturing plumber. I need scarcely to remind listeners and readers of the immense contribution of Scotland to most forms of engineering. Of this theme, more later. Educated at Ayr and Wallacetown Acadamies he briefly studied arts at Glasgow University before joining his brother, John, on the Victorian goldfields in 1854. Without formal qualifications he joined the Railways Department at Geelong, became an £800 per annum (a very good salary in those days) engineer in 1859, by 'learning on the job' (Waterson, D.B., *Personality, Profit and Politics*: Thomas McIlwraith in Queensland, 1866-1894, Brisbane, 1984).

McIlwraith joined Cornish and Bruce the contractors for the Melbourne to Bendigo Railway as an engineering overseer. Big Hill tunnel near Bendigo is still worth a visit. He made substantial personal profits, saving thousands on stone from cheaper quarries.

McIlwraith moved to Queensland in 1864 and invested heavily in Maranoa and northern pastoral and sugar properties forming the North Australian Pastoral Company, a pioneer example of a vertically integrated company breeding animals, fattening them, killing and freezing them and exporting frozen meat to Britain. Here was the entrepreneur well aware of the the engineering and technological breakthroughs that were the foundations of the frozen meat trade. (Waterson, *op. cit*, pp. 10-13).

Establishing the Darling Downs and Western Land Company, the Queensland Investment and Land Mortgage Company and the new Queensland National Bank with a mixture of British and local capital, McIlwraith was forced into exile in London, a ruined man lucky to avoid gaol for fraud although some fruitful assets had long been transferred to his wife under the Married Women's Property Act. Gold mining, sugar and copper speculation were, by the Depression of the 1890s, also unsuccessful.

McIlwraith entered colonial politics in 1870, became Minister for Public Works and Mines in 1874 and Premier and Treasurer in 1878-83. An advocate of massive state borrowing for public works, a land-grant Transcontinental Railway – still talked about – the stimulation of large-scale mining and pastoral enterprises and banking and other financial manipulations. In 1890-93 he was the financial power behind the Griffith-McIlwraith Coalition during the great-depression, put down the shearing strikes, quarrelled with the Bank of England and concealed the parlous state of the Queensland National Bank and his own massive overdraft jointly held with the General Manager, Colonel Drury.

He flirted with crude Social Darwinism, Queensland nationalism, advocated imperial expansion through engineering artefacts and single-handedly annexed part of New Guinea against the wishes of the British Colonial Office. McIlwraith even managed to win the unalloyed approval of Francis Adams in his seminal work, *The Australians: A Social Sketch*, London, 1893, pp. 77-78).

There is another point linking McIlwraith's notion of rational improvement, personal performance and the use of engineers to alter the world to western standards. 'Andre' Maurois was aware of this aspect of the nature of British material colonisation: 'Aurelle, rather dazed, fuddled with the Indian sun and the scent of wild animals, at last realised that this world is a great park laid out by a gardener god for the gentlemen of the United Kingdoms (Maurois, Andre, *The Silence of Colonel Bramble*, Melbourne, 1940, p. 33).

Progress and transformation, then, was the goal. But it was to be the material program of the railway engineer turned speculator and improving pastoralist. (Waterson, *op. cit.*, pp. 9. 29). He firmly believed in both the imagery and the transforming power of technology and enthusiastically lauded the practical men of the world in his 1875 lecture 'The Romance of Engineering'. Every word of Carlyle's saga of steam would have earned McIlwraith's unstinted approval:

> Of the Poet's and Prophet's inspired message and how it makes whole worlds, I shall forbear to mention: but cannot the dullest hear steam engines clanking around him? Has he not seen the Sottish brains – Smith's idea (and this but a mechanical one) travelling on five wings around the Cape and across two oceans… at home not only weaving cloth, but rapidly enough overturning the whole system of society… preparing us, by indirect but sure methods, Industrialism and Government of the Wisest (Carlyle, T., *Signs of the Times*, London, 1869, pp. 317-18)

But there is a dichotomy here which Carlyle and later Ruskin acknowledged. Mechanical progress through engineering triumphs may transform the world but what of its effects on human beings, on individual expression and artistic creativity and passion? Carlyle in his *Sartor Resartus* was contemptuous of 'Liverpool Steam Carriages' while Ruskin continued to stress 'Romantic Fairness against a philosophy of gain and wealth' and basically held a nostalgic feeling for long-dead rural life and held engineering solutions as, by implication, no answers for ones population and poverty, mass ignorance and disdain for beauty (Ruskin, John, *Unto This Last: Four Essays in the First Principles of Political Economy*, 7th ed., London, 1890, esp., pp. xi, 156, 167-70).

Here the influence of Samuel Smiles (1812-1904) should be mentioned as a widely-read publicist – paralleling McIlwraith's 1875 lecture. Like McIlwraith, Smiles was also a Scot and can be canonised as the originator of Business and Engineering history (Mathew, H.C.G., 'Samuel Smiles' in *Oxford Dictionary of National Biography*, ed. Mathew, H.C.G. and Harrison, B., 50, Oxford, 2004, pp. 1001-4).

Smiles was a product of the Scot's Enlightenment like so many of his subjects. It was no accident that the University of Glasgow was the first institution in the Empire to have a Chair of Engineering and it is most appropriate that Dunedin, the most Scottish of all Antipodean cities, should host this conference. Smiles stressed the virtues of self-help, self improvement through industry and education as well as duty, perseverance and meticulous mathematical calculation, all qualities which are still part of the engineering profession (Smiles, Samuel, *Lives of the Engineers: The Steam Engine*, Boulton and Watt, London, 1878, esp., pp. 382-3, 406-09. There are a further four volumes dealing with canals, lighthouses, roads, locomotives and bridges).

But for McIlwraith, a successful amalgam of political fireman and development engineer the fulfilment of his dreams and the continuation of his political life depended on Queensland rapidly increasing its population by immigration and natural increase, massive capital investment from Great Britain, high prices for primary products and minerals and world economic expansion and stability. But as the depression of the 1890s deepened McIlwraith's cleverly woven tapestry began to unravel. Then, too, the human machine began to break down. His physical disease, peripheral neuritis, caused by a Vitamin K deficiency and resulting from viral infections, venereal disease, lead poisoning from his father and brothers' lead processing workshops or alcoholism – take your pick – increasingly influenced his ability to deal with a series of crises which went far beyond his ability to diagnose or control. Great forces, as Marx observed in the *Manifesto of the Communist Party* – just when McIlwraith was moving from Victoria to New South Wales were in motion. Indeed part of the manifesto can be read as a hymn to the unleashed powers of engineering in the Nineteenth Century but continued in the Twentieth by the Soviet Union, the People's Republic of China and other States concerned to master their environs.

> The bourgeoisie has created more massive and more productive forces than have all the preceding generations together. Subjection of Nature's forces to man, machinery, application of chemistry to industry and agriculture, steam navigation, railway, electric telegraphs, clearing whole continents for cultivation, canalisation of rivers, whole populations conjured up out of the ground – what earlier century had even a presentiment that such productive forces slumbered in the lap of social labour? (Marx, K., and Engels, F., *The Communist Manifesto*, London, 1847, new ed., Moscow, n.d., pp. 50-51).

Engineering was thus essential, throughout the world, including the colonial areas as Michael Adas has shown, of the creation not only of new societies of settlement but a variety of interlocking and interacting frontiers, the first wave of which we can now see as the deepening hurricane of globalisation (Adas, M., *Machines as the Measure of Men: Science, Technology and Western Dominance*, Ithaca, 1989, esp., 184-97, 220-240, 357-385).

I do not intend to analyse McIlwraith's political skills and superficial reasons for his eventual downfall just noting that his name, unlike that of Alan Bond, is not attached to a university or even a business school, but only an obscure mountain range in North Queensland, a scattering of street names, a couple of portraits hidden away in libraries and, more significantly, engineering scholarships at Queensland University. Even his grave is situated close to his birthplace at Ayr and near a row of Empire airmen's graves, the victims of training accidents at Turnberry airfield, a few miles away. Their deaths were, it has been remarked, a consequence of the planet's first industrial World War which, as we shall see, was essentially a murderous engineers conflict – although few military leaders recognised this at the time.

McIlwraith may have been a polymath but throughout – the exploding frontier of Western penetration and exploitation engineers were at the forefront of the advance. Henry Lawson, when commenting on the failure of the shearer's strikes that, by moving men, arms and materials, the state had crushed, remarked: 'through railways now the mighty bush is tethered to the world'. Lawson went further in 1904 with his nationalist plea for the creation, not of noble shearers and bush denizens of Russel Ward's *Australian Legend* and Bean's Anzac celebration of outback blood and soil virtues, but the metropolitan Australian engineer. The verse is worth quoting in full:

AUSTRALIAN ENGINEERS

Ah, well! but the case seems hopeless, and the pen might write in vain;
The people gabble of old things over and over again.
For the sake of the sleek importer we slave with the pick and the shears,
While hundreds of boys in Australia long to be engineers.

A new generation has risen under Australian skies,
Boys with the light of genius deep in their dreamy eyes—
Not as of artists or poets with their vain imaginings,
But born to be thinkers and doers, and makers of wonderful things.

Born to be builders of vessels in the Harbours of Waste and Loss,
That shall carry our goods to the nations, flying the Southern Cross;
And fleets that shall guard our seaboard – while the East is backed by the Jews—
Under Australian captains, and manned by Australian crews.

Boys who are slight and quiet, but boys who are strong and true,
Dreaming of great inventions – always of something new;
With brains untrammelled by training, but quick where reason directs—
Boys with imagination and keen, strong intellects.

They long for the crank and the belting, the gear and the whirring wheel,
The stamp of the giant hammer, the glint of the polished steel,
For the mould, and the vice, and the turning-lathe – they are boys who long for the keys
To the doors of the world's mechanics and science's mysteries.

They would be makers of fabrics, of cloth for the continents—
Makers of mighty engines and delicate instruments;
It is they who would set fair cities on the western plains far out,
They who would garden the deserts—*it is they who would conquer the drought!*

They see the dykes to the skyline, where a dust-waste blazes to-day,
And they hear the lap of the waters on the miles of sand and clay;
They see the rainfall increasing, and the bountiful sweeps of grass,
And all the year on the rivers long strings of their barges pass.

But still are the steamers loading with our timber and wood and gold,
To return with the costly shoddy stacked high in the foreign hold;
With cardboard boots for our leather, and Brum-magem goods and slops
For thin, white-faced Australians to sell in our sordid shops.

(Henry Lawson, *Collected Verse*, edited by Colin Roderick, Volume Two, Sydney, 1968, pp. 92-93).

Ironically, a decade later it was an Australian engineer of Jewish birth, Sir John Monash who led the First AIF to its great victories and who successfully combined logistics, airpower, tanks and other industrial material in a unique and devastating fashion (Serle, G.S., *John Monash*, Melbourne, 1982).

His contemporary Herbert Hoover, an American mining engineer with a stint on the West Australian goldfields and a brilliant organiser of relief after the First World War, could not adapt his skills to overcoming the worst effects of the Great Depression in the United States. While this President is remembered largely for his omissions and the construction of the Boulder (later Hoover) Dam on Colorado River, his successor F.D. Roosevelt paradoxically used the talents of the engineers on the great Tennessee Valley Authority's schemes and other massive construction feats. To race ahead it was the Corps of Engineers under General Leslie Groves that provided the infrastructure that produced the atomic bomb while the TVA and New Deal provided much of the conceptual influences behind the Snowy Mountains power and irrigation undertaking, itself Australia's largest and most important Twentieth Century engineering feat, presided over by a son of a nation that has produced far more engineers than its population might have been expected to germinate, Sir William Hudson.

But I digress. The autobiography of the Dublin-born railway engineer C.O. Burge whose efforts as a servant of the British Empire spanned five continents. His creed came straight from the British Institution of Civil Engineers: 'The art of directing the great sources of power in nature for the use and convenience of man, as the means of production and of traffic in states both the external and internal trade' (Burge, C.O., *The Adventures of a Civil Engineer: Fifty Years on Five Continents*, London, 1909, p. 37).

Burge believed with Smiles and McIlwraith that 'to the engineer we owe much to the moral and intellectual progress of mankind' (*Ibid*., p. 38). Working on the great period of Indian Railway construction which, with the English language and a form of social democracy was the Raj's contribution to India, Burge also worked on bridges, Cape of Good Hope railways and, closer to home, what was until the Sydney Harbour Bridge's construction (1932) the largest project in New South Wales, the Hawkesbury River Bridge (1889). As Resident Engineer he and the American contractors employed techniques unrivalled for boldness, innovation and effectiveness. Indeed, the seven piers carrying the structure are still in existence long after the bridge itself was replaced. After the bridge was completed Burge supervised the removal of the Devonshire Street Cemetery's inhabitants who, in the interests of progress, made way for the new Sydney Central Railway Station (*Ibid*., pp. 256-62).

As an interesting sidelight Burge observed that many engineers were also Freemasons. The connection of both crafts to 'the great Architect of the Universe' is clear. Burge was part of Buchanan's 'motley crew' of artisans, practical craftsmen who were mainly of a conservative political bent although, in contradiction to Ruskin, were often of a artistic bent with an ability to see inventions and their implementation in the mind's eye (Buchanan, R.A., 'Gentlemen Engineers: The Making of a Profession', *Victorian Studies*, 26, 1983, pp. 410-11. I am indebted to Professor Caroll Purcell for these and other observations. Purcell, C., *White Heat, People and Technology*, Berkeley, 1994, pp. 47-48).

But even before the disastrous Great War the day of the independent innovative engineer was almost over as a dependence on mathematical formulae and computer models manipulated by a variety of well-trained experts provided 'information rather than insight, and labour marshalled by scientific management' (Purcell, *op. cit*., pp. 47-48). To these developments I would add the demands of corporate and finance capital on politics, both social democratic and authoritarian and the growth of a consumer and rapid replacement society let alone the complexities of an inventor/ engineer increasingly at the disposal of a military-industrial complex (Ferguson, E., 'How Engineers Have Lost Touch', *American Heritage and Technology*, 8, 1993, pp. 16-20).

From the beginning of the Twentieth Century as power shifted from Western Europe to the United States engineers were employed by large corporations such as General Electric, Ford, General Motors and United States Steel. The Europeans as craftsmen/ engineers were still capable of great innovations as radar, penicillin, computers, atomic physics and jet propulsion demonstrated but mass-manufacture was often transferred to the United States and then to Japan and now South Korea, China and India.

If as Purcell claims, the mechanic/ inventor Henry Ford and Frederick Winslow Taylor, a consulting engineer were 'the midwives of the Twentieth Century… it was a mass project based on the principles of power, accuracy, economy, speed and recognition'. These are qualities which all engineers both old and new recognise, but which can be distorted by society's obsession with a mechanical mastery over both nature and other human beings. A useful corrective to this is the screening of Fritz Lang's 1927 epic *Metropolis* or the rapid acceleration into reality of Aldous Huxley's *Brave New World* and the discovery and engineering of the human genome (Purcell, *op. cit*., pp. 94-7). But increasingly engineering's role in the provision and distribution of clean water through sewers, dams, recycling and harvesting techniques will become even more important in the 21st Century as pressure on existing supplies and the effects of climate change become more apparent. C.Y. O'Connor's Western Australian Goldfields pipeline and Maurice O'Shaughnessy's Sierra Nevada-San Francisco water supply are perhaps, like Watt and Stephenson's Steam engines of the previous century, harbingers of a new age celebrated not only in the United States but in Lenin's Soviet Union symbolised by the giant Dnepropetrovsk Dam on the Dnieper. It is no accident that the engineer, unlike army officers, intellectuals and party ikons remained virtually untouched by the purges of the Stalin years (see: Sinclair, B., 'The Profession of Engineers in America', in Purcell, C., *A Companion to American Technology*, Oxford, 2005, pp. 363-384).

I conclude with some observations on the long journey of the engineering fraternity from Watt to entrepreneurs such as McIlwraith, to the corporate team player and now a member of a profession which includes most, if not all facets of our daily life from bio-mechanics to aircraft, from engines to atom and from computers to communications. The challenges facing the profession have been well summed up by Rosalind Williams:

> Their time (little e-engineering) is past and will not come again… but it has left a legacy that provides a solid foundation for the future; confidence in the ability to solve problems, energy and hard work; the habit of teamwork… the delicate balance between investment in and chitance from capitalism; the belief in community and progress; the assumption of responsibility for the material world.
> We are not confronting the death of engineering any more than we confront the death of nature, history or science… But it will be especially painful to make the transition from acting in a familiar mould… to acting in the larger and more disorderly world (Williams, R., *A Historian Confronts Technological Change*, Cambridge, Mass., 2003, pp. 87-88).

Whether or not the eighteen engineer-trained members of the twenty-five strong Chinese Politburo and the new Japanese Prime Minister also a graduate engineer will make a difference remains to be seen (*Encyclopedia Britanica Yearbook*, 2013, p. 415). But I started with a Scot and will finish with a note of cheer to all engineers. Lord Brougham's epitaph to Watt on the colossal monument to the genius in Westminster Abbey is still worth quoting:

Not to perpetuate a Name
Which must endure while the Peaceful Arts flourish,
But to show
That Mankind have learned to honour those
Who best deserve their gratitude,
The King,
His Ministers, and many of the Nobles
And Commoners of the Realm,
Raised this Monument to
JAMES WATT,
Who directing the Force of an original Genius
Early exercised in Philosophic Research
To the Improvement of
The Steam Engine,
Enlarged the Resources of his Country,
Increased the Power of Man,
And rose to an Eminent Place
Among the most illustrious Followers of Science,
And the real Benefactors of the World.
Born at Greenock, 1736.
Dies at Heathfield, in Staffordshire, 1819.

(Smiles, S. *op. cit.*, p. 404)

D.B. Waterson.

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Sydney's Birthplace Walk Podcast

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SUMMARY: *The Sydney's Birthplace Walk is a heritage walking tour that is freely available as an enhanced podcast. It is based on an existing walking tour developed by Heritage Engineer, Michael Clarke, and describes the places, people and engineers that established modern Sydney. Set in the historic Rocks area, the two and a half hour tour provides listeners with just over an hour and a quarter of content, consisting of audio commentary, still photographs, navigation instructions, maps and background audio. User centred design strategies were adopted in the analysis phase to understand the context in which the original walking tour was presented. This paper discusses the design, development and production of an enhanced podcast highlighting the importance of the copyright issues surrounding the release. Availability via the iTunes Store podcast section will also be described. The paper further explores the future of personal mobile and location aware devices for advocacy and education in heritage engineering.*

1. INTRODUCTION

The widespread availability of mobile devices (i.e. phones, music players, navigation devices) with both audio and video media playback provides an increasing audience with the ability to download content and take that content with them on a journey. In the context of heritage, we would like people to be able to find historical content related to a place of interest, download the relevant information to their device and listen to it in-situ. In addition to audio, the user can view imagery to both assist in orienting themselves in the environment and to show what this place looked like in the past. From the institutional point of view the consumer ownership of mobile devices removes the need to provide equipment hire and headphone cleaning facilities.

The self-guided walking tour is a ubiquitous tourist instrument that allows the motivated traveller to discover a series of places in an unfamiliar part of a foreign city. In paper form, it is typically found in a guidebook or as a single- or double-sided paper fold out that reveals to the traveller a map embellished with a sequence of numbers that are optionally connected with a suggested route. Alongside the map is the legend that associates the numbers with named places of significance. Depending on the design layout, the traveller may need to cross reference the numbers or names with a separate detailed description of those places. Dexterity may also be required to flip page sides or fold and unfold. Simultaneously, the traveller locates and orients themselves in the real world, based on the map they have before them. Throughout the world there is a familiar sight of confused people rotating maps, and reading street signage to understand where they are and where they have to go.

The cognitive load imposed on the unfamiliar traveller is high. Attention is split [1] between different pieces of information such as the place on the map and the description located on the other side of the page (see [2] regarding cognitive load and map reading). There is also a great deal of excise ([3]) involved in trying to find the places of interest. The traveller's goal is really to explore places of interest, not spend time trying to interpret a map.

The guided walking tour allows the tourist to follow an expert who is familiar with the territory, thereby avoiding the sense of being lost. Places of interest are pointed out and described in more depth and interactivity than a paper guide or map. A one-to-many two-way conversation takes place during these tours, allowing visitors to ask questions.

With a mobile self-guided tour, the challenge is to make an informative experience that also removes having to deal with the physical paper map experience. The experience should embody "play and start walking" approach. The initial approach considered how to provide a linear sequenced tour in a more engaging manner that leverages off-the-shelf mobile media technologies (circa 2007-8), where possible, making the traveller feel like they are being guided by an experienced and knowledgeable guide.

2. LOCATIVE MEDIA - PAST EXPERIENCE

This project is influenced in part by our design and public presentation of several art+science research projects that have explored the use of sound media in location sensitive art pieces. In 2004, AudioNomad (Linkage Project LP0348394 2004-2007) was one of the first projects to be funded under the Australian Research Council and Australia Council for the Arts, Synapse Initiative [4].

The aim of the funding initiative was to bring artists and scientists (and engineers) together to explore new and novel research collaborations. Through this project AudioNomad deployed 2 major artistic pieces that used geographic location to trigger sound [5, 6]. A novel aspect of this work is the use of a 12.2 speaker circular speaker array, which provides an immersive listening experience, allowing sound to be virtually positioned 360 degrees around the listener. Both projects were presented on boats and provided listeners a composition of sounds augmented over the real landscape. Sounds could be virtually attached to places in the physical landscape and as the boat moved, the listener could hear those sounds coming from a fixed position in the environment (Figure 1).

Figure 1. *Using a speaker array the AudioNomad projects could create the sense that a sound was coming from the island in the physical landscape.*

The audio content (designed by Nigel Helyer) included acoustic examples of sonic art, recordings of nature, industrial sounds, historical narratives; the latter of which featured archival recordings. These examples were highly layered, presenting an acoustic environment far richer than what we normally experience.

These large-scale public surround sound artworks used gigabytes of audio data, multi-channel audio hardware and the processing power of a desktop computer.

3. THE CONCEPT

The Sydney's Birthplace Walk provided a new opportunity to reconsider location-based content but with reference to off-the-shelf consumer technology. A walking tour on a mobile device (circa 2007) for pedestrians has design limitations: limited storage space, finite battery life, limited location-awareness (if any) and stereo audio.

Michael Clarke, heritage engineer has been conducting guided walking tours and boat tours since 1994, producing a guide book [7] and has personally led around 2000 people on tours to places of Engineering significance in Sydney [8]. He is passionate about heritage, drawing on his own experience as a civil engineer. Michael collaborated in the development of this podcast providing a wealth of experience, having researched this topic for more than a decade.

In previous AudioNomad projects, a researcher who did not have domain-specific, historical knowledge conducted content research. The outcome of that research uncovered archival imagery and texts that could be utilised as the script. Typically this process took 2-3 months [9]. In the development of this walking tour, Michael with his knowledge and experience produced a script within a couple of weeks specifically tailored to the podcast. His collection of imagery provided was an invaluable starting point. From this project, our experience demonstrated that working with an expert familiar with the content increases the efficiency of the pre-production process.

4. PROCESS

4.1 A User Centred Approach - Observing the Guide Process

Taking a user-centred design approach [3], the first step was not to build a system, but to actually go on the walking tour with the expert guide. The aim of this excursion was to understand both the experience of the listener in the actual setting and how the guide conveys the content. This was slightly less realistic since it was not conducted with a typical sized group. It was just the researcher/designer and the expert guide.

Audio recordings and some site photographs were recorded. The observation audio recording was carried out with a simple digital recording device (Griffin Microphone + iPod).

Recordings could be used to aid developing a script, but in our case the expert was part of the pre-production team so we did not need to refer to the recordings to develop the script process.

From the first walk, the observations indicated a need to provide both audio *and imagery*. Audio was obvious, but an A3 folder was used to show relevant pictures that complemented the commentary. As part of the commentary, the guide used hand gestures to point to things and described places to look at based on the listener's relative position.

Places visible in the environment were mentioned within the commentary (eg. "...the brick building over here with the chimney...") to both draw the listener's attention to a physical area in the landscape and to lead into the next part of the tour. Instructions to ask the listeners' to move around were spoken. With the guide, the physical gestures (i.e. pointing and walking in a particular direction) are clear clues for the listeners to follow. In a mobile device context, this isn't possible. So there is a need to orient the listener in a particular direction and have them move to a specific place, using visible cues present along the route.

4.2 Script Development

Following the observation exercise, the next stages were to develop a script suitable for a studio recording and identify which imagery was relevant and where it should be included relative to the script material. The content expert developed scripts and the placement of images relative to the script.

The original script described the walking instructions between each point of interest but was refined to support a second narrator giving those directions. Specific visual cues were also mentioned in the navigation scripts.

Navigation was adjusted to ensure that pedestrians followed sign posted street crossings. For safety reasons, the script does not encourage the walker to be listening to commentary whilst walking. The idea is to have the person stop at a place and listen to the main commentary and then hear the cued walking instructions, press pause and walk to the next destination. When at the next point in the tour, the play button is pressed.

4.3 Navigation Media Content

Whilst maps give the user an aerial view, they do not provide an "on the ground" perspective. Photos were taken from the pedestrian point of view to help the user orient themselves in the environment (Figure 2). The photos are sequenced with animated map images. An additional visit was conducted to take photographs of the immediate surroundings to help the user orient themselves to visible landmarks.

The navigation photos assume that the user stays on the designated path and has not deviated off the planned route. Providing corrections would require a device that could support alternative pathways and know its position. In this instance, the devices used were not programmable, not location-aware and could only use a linear sequence of media.

Figure 2. *Image sequence taken to assist people find the stairs at the north end of the Overseas Passenger Terminal. Taken from the pedestrian perspective.*

4.4 Mapping Content

Mapping content is provided under licence from MapData Science Pty Ltd. The licence requires that the maps be provided as static images. The images are overlaid with a walking path that shows the starting point (green rounded), the stages to walk (blue path, with white highlight to show the current stage) and the destination (red rounded square) of the next leg of the tour (Figure 3). Interleaved between the map imagery are the photos taken from the walker's perspective (Figure 2).

Simple map illustrations rather than aerial photographs were used in all but one map given that most people would be unfamiliar with roof structures when standing on the ground (Figure 3).

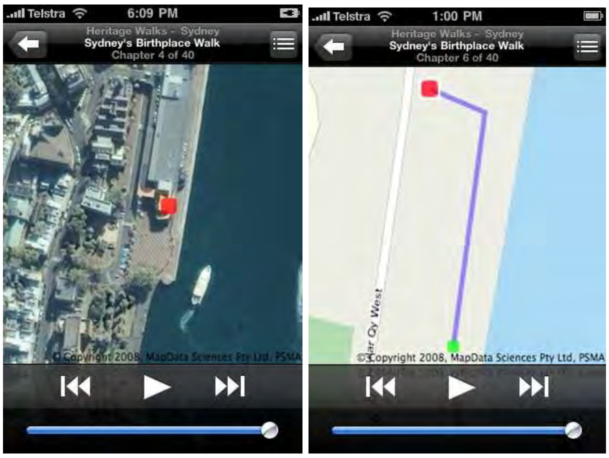

Figure 3. *Aerial vs Illustrated map showing the Overseas Passenger Terminal*

4.5 Podcast Development

Podcasts on the iPod platform were considered for this version because of the widespread availability of the devices, the ease of use in being able to download the content via the iTunes application (on both Mac and Windows platforms) and the ability to embed photographs using the enhanced podcast format. A movie-based format was considered as an alternative but the overall file size, potential compression artefacts and the fact that still imagery was the primary source of visual material, led to using the enhanced podcast.

MPEG3 audio files, a commonly used format available on a wide range of devices, would have been appropriate if the content consisted only of audio, without images. The script makes references to images, so in this version, removing the images and leaving the recorded audio would have created some confusion for the listener.

Tools such as Apple's GarageBand and Soundtrack Pro have functions that enable creating enhanced podcast content.

4.6 Audio Recording and Editing

Using a completed script, the narration was digitally recorded with a professional voice microphone in a quiet room. The domain expert was used as the narrator. The voice quality was consistent with the goal to provide a friendly guide whose voice gave the sense that they were there beside the listener showing them the places being described. The voice has been described by a trained voice professional as a warm, friendly voice, which is in keeping with the content.

A professional voice artist was used to record the navigation instructions. A female voice was chosen to contrast the main content giving the listener a cue when to listen and when to walk.

Editing the audio recordings was required to extract the most appropriate recording "takes". Sometimes the final take for that section was used, other times because of errors, multiple takes were appropriately spliced together. Editing of a professional voice artist compared to a non-professional is a significant cost/time consideration. A professional voice artist is more consistent and the way that errors are handled does help the editing process. For a non-professional, they may not realise that a mistake has been made or might repeat a subsequent take in a slightly different manner. Admittedly, the complexity of the navigation instructions is simpler than the narration, so the types of mistakes that are encountered are also simpler. In our case there is a trade off between a knowledgeable voice versus a professional voice.

4.7 Image Use, Rights and Copyright

A significant amount of time was devoted to managing the legal aspects of image use. Under copyright, the use of images in an electronic enhanced podcast is quite different from personal use, research purposes or use in print material. To redistribute the content in electronic form imposes different constraints and a specific licence agreement was required. In order to manage this process, a database of all images to be included was developed. From this database, reports were generated to provide the rights holder with a description of the images that were required. Many of the existing images were already available through on-line searchable catalogues. The resolution required for enhanced podcasts is not high (unlike print use) so the on-line version provided sufficient resolution and we did not require the rights holders to reproduce high quality imagery. Permission to reproduce all included images was obtained from the relevant institution.

4.8 Assembling

Once the audio content and image media were edited the process of assembling the experience took place. Audio was separated into different places of interest and sectioned off on the script. Audio was placed and then imagery synchronised to the precise point where it was mentioned in the commentary. Several iterations were typically required to fine-tune the audio and images.

Chapter markers where used at the beginning of navigation instructions and at the beginning of each place. This provides the user with a quick method for skipping between different parts of media. On the iPhone and iPod touch interfaces the user can view the complete name of the chapter marker (Figure 4), so naming the chapters with something meaningful is important. In the field, the chapter markers allow the user to tap the back chapter button to start the current section again.

Figure 4. *Chapter markers enable the listener to choose, based on the name of the place*

In addition to the chapter markers, there are musical audio samples that correspond to the beginning and end of navigation instructions. These are consistent throughout the entire tour so the listener learns when navigation is about to commence and the female guide voice commences. There is an additional musical interlude to wait for the listener to press the pause button.

During the editing process, the script is read constantly, to confirm that the recorded audio has no errors in the dialogue and that any hesitations are removed or corrected. The synchronisation and duration of the images is also verified. Section by section, each is carefully reviewed, and then whole sections are confirmed and finalised against the script. As the content grows in duration, so too does the time to review.

4.9 Device Testing

The content can be tested within the authoring application or as a media file in a media player, like Quicktime Player (Figure 5). But it is also important to audition the content on a target device. Fortunately, the same files can be distributed and played on other computers; so having other editors (and expert guides) listen to the content during the editing process is both possible and beneficial.

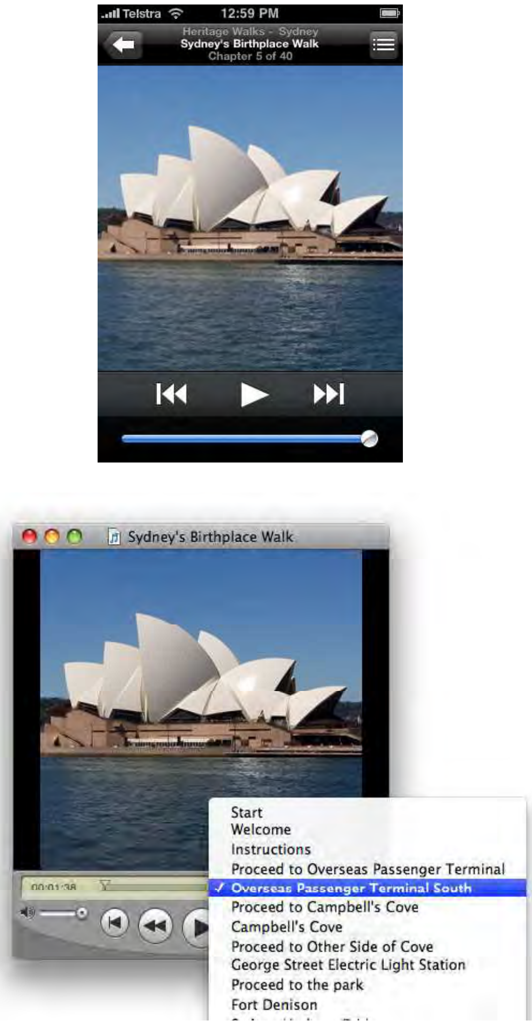

Figure 5. *Podcast playback on iPhone 3G and Quicktime Player with chapter markers visible*

4.10 Additional Audio

Following the near final layout of the commentary and images, audio effects can be added. In this case we enlisted AudioNomad collaborator and sound artist, Nigel Helyer, to provide the ambient audio layer. There are various background audio samples that have been added to create a more interesting sonic experience. As an example, there are footsteps heard when presenting navigation instructions.

Some additional original audio was composed and added and finally the audio mixed down to balance out varying audio levels.

4.11 Availability Via iTunes Podcast Store

Whilst the iTunes store is the leading on-line retailer of music [10, 11] it also provides links to freely available podcast content. Apple does not host the actual media files, instead it provides a library of approved links to

XML files [12] and, as the content provider, you are required to host the media and XML file. The user does not directly see the XML file, but after searching for content in iTunes sees a content page with each episode listed (Figure 6).

The XML file defines each episode in the podcast and the link to the media location. Currently, we have only one episode.

Content is not restricted to audio files. Other media files (including movies) could be defined as well as portable document format (PDF) files. In our case, we are required by the University (and licensors) to provide the terms and conditions of use in written PDF form.

The content developer submits the feed for approval to be included on the Apple podcast store. Once approved, the podcast section of the store will maintain a page for your podcast episodes.

Figure 6. *Sydney's Birthplace Walk podcast displayed with iTunes application*

Potential users can find the content by searching the iTunes store for podcasts or using a specific URL, alternatively you can provide users with a web link that will open their local iTunes application with your content displayed on open. This greatly enhances the desktop user experience for users. This is now supported via the iTunes store on mobile devices.

5. TECHNICAL SPECIFICATIONS

Content Duration	1h 17m 56s
Content File Size	71,659 KB
File Format	m4a

Number of Images 346
includes photos, artwork, animated maps, logos and titles

6. WEB SITE

A web site was created for the tour [13]. This contains a basic introduction to the tour, a full list of image credits, terms and conditions and a link to download the content via iTunes.

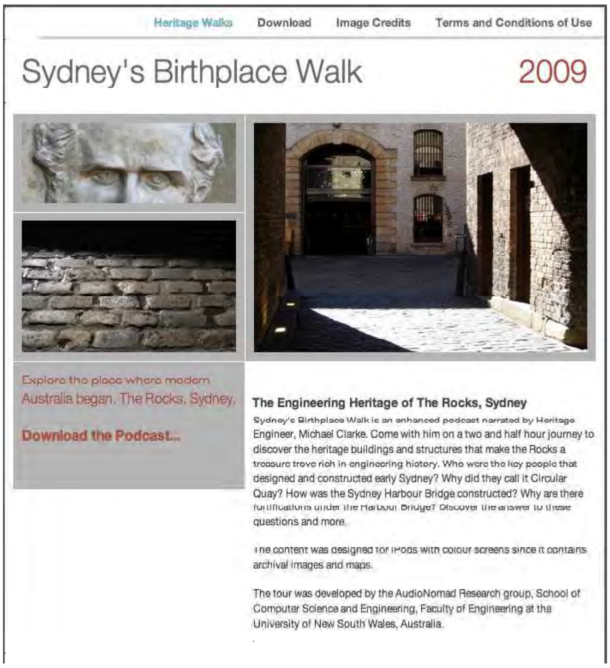

Figure 7. *Web site to introduce and download the podcast content*

7. MEASURING USE

7.1 Logs

The media file (m4a format) can be found via two different ways. Users can find the top-level page of the web site and navigate to the download page or the content can be found by searching the iTunes store podcast listings. Both end in iTunes downloading the file. The specific file is never directly loaded by the user (ie. The user does not see the file URL).

On the web download page, when the user clicks on the provided link, the iTunes application will open on their desktop and present them with the AudioNomad Research Group podcast page (Figure 6). We can therefore track visitors to the main web page and the download page, but cannot directly count the number of downloads.

On the iTunes store they can search for the podcast (using various search categories) or by seeing similar podcasts that they or others have subscribed to. Following an iTunes search, in order to display the episodes, the XML file hosted on our web server, will be accessed and downloaded to the user’s computer. The XML file provides an opportunity to track those interested in the content. It does not however, directly count the number of actual downloads.

The media file is hosted on the University media server and unfortunately there are no publicly available log statistics. So tracking of the precise number of downloads is not possible with the current configuration. Unfortunately, Apple iTunes store does not provide download statistics.

Google Analytics [14] has recently been used to track some of the web pages. But web site visits represent only a fraction of the traffic.

Using web access to the XML file, we measured that there have been 3401 access to the file from 506 unique Internet addresses over a 60 day period from July 21 - September 21, 2009. The number of unique addresses should be slightly smaller since there are some contiguous addresses which are most likely from the same machine but have a different network assigned address. There are two addresses that are from our school domain range. Web spiders may also have accessed this file but we have not excluded those. Once subscribed, the iTunes application will periodically check the XML file for updates, so this explains why there are many more accesses than unique Internet addresses.

In the same period, Google Analytics reports 31 visits to the web site. 54.84% being from referring sites, 35.48% from direct traffic and 9.68% from search engines. Bounce rate is 22.58%, which describes whether initial users immediately go to a different site upon viewing one page. A low number is better. 2.9 pages are being viewed, and the download page is one click away from the point of download.

Based on this data it would appear that most of the interest is coming from iTunes users, not the web. We have not performed any search engine optimisation or broad distribution of the web site address. Given the baseline data that we have collected we are now in a good position to see the effect of specific campaigns to advertise the content.

iTunes does allow consumers to review podcasts. To date we have only had one (positive) review.

July 29, 2009

This is a wonderful resource, superbly researched and always fascinating. Well worth the download.

Five star rating.

7.2 Survey

A 29-question survey has been developed but has not yet been released. In this survey we aim to understand the experience gained by users when using the tour and their desire to download more heritage podcast content. We hope to deploy an electronic survey to assist in the capture and analysis. A pilot test with a visiting engineer who took the walk was very encouraging.

8. OUTCOMES

Based on the informal feedback, the content provides an engaging experience that helps people discover places and understand facts about an area that is both informative and entertaining. Using an experienced guide, who has a high level of familiarity with both the place and content, has contributed to the efficiency in our production process.

Podcasts need not be limited to audio only experiences. With the enhanced podcast, archival images and photos can be included to improve the user experience. However, the image content should not be the focus of the media experience since we would prefer to see the visitor engage with the real environment than be focussed on a small screen throughout their tour.

Including animated maps, interleaved with pedestrian perspective images and relevant audio navigation instructions supports the process of way finding in the environment, alleviating the need for cumbersome paper maps.

Planning to devote a considerable amount of time to the legal aspects is important. Setting up systems to automate the cataloguing process helped reduce the manual tasks involved.

To date, our experience without engaging in web advertising or search optimisation strategies has indicated that the iTunes podcast store provides a mechanism that enables people to find heritage content.

Listening to some other commercial productions, the use of a professional voice talent can produce a media title that does not sound authentic. The voice, does not give the sense that they are knowledgeable about the topic; it is merely something that has been read, professionally. There are some good examples that give the sense that the narrator is very familiar with the place that they are presenting [15, 16].

9. THE FUTURE

9.1 Education

The high prevalence of the iPod media device family, especially in the high school demographic range, provides an opportunity to reach markets that would not typically be searching for heritage information. Students in this age group are very familiar with the consumption of media and podcasts, so presenting the content in this format may help engage this audience. A question that we are still to answer via the forthcoming survey is the acceptance level of the style of content and voice of the commentator against different demographics.

Since the content is not limited to being played on a mobile device, and can be played on a desktop computer, applications in education could support the student listening to the material before visiting a site, hearing the content in-situ and then reviewing the content as part of additional exercises following the visit. This could enhance learning outcomes through reinforcement. To extend this concept, variants of the content could be produced to support the before, during and after experience, avoiding mere repetition.

9.2 Devices

Programmability of newer devices provides a great opportunity to consider interaction beyond simply playing a linear media file in sequence. Since the release of the podcast, the device market has changed considerably. Devices such as iPhone and phones that run on Google's Android operating system [17] come equipped with cameras, GPS, accelerometers and compass capability. These features make it possible to consider different ways to initiate and interact with the basic tour content.

The devices are both phones and network capable devices, and they use both 3G GSM and WiFi network technologies. However, given the data charges for 3G, downloading a single 80MB piece of content may be cost prohibitive, especially for the mobile international roaming traveller. So the spontaneous download scenario is still a challenge, mostly due to economic constraints. Currently, we are geared towards the organised tourist who downloads before they leave a desktop internet-connected machine. In some cases, the user is probably listening to the entire content on their desktop computer prior to visiting.

9.3 Interaction

This style of media; a commentator guiding a visitor around with photos and maps, is only one form of interaction. Given the explosion in the mobile game market, there are different ways to engage with the audience. Geo-caching [18] and adventure style interactive mobile experiences [19, 20] are good examples of what is currently possible. The challenge is to design compelling user experiences that can reach a range of demographics. Where possible rapid re-purposing and reuse of media will assist in deploying to a variety of platforms and interaction experiences.

10. CONCLUSION

At the end of 2007, we began the process of producing a podcast media title for Sydney's historic Rocks area. The starting point was an existing walking tour conducted by heritage engineer, Michael Clarke. Over the next four months, we carried out an observation of the guided tour, developed scripts, recorded content, gathered and researched imagery, maintained records for copyright and legal clearances, negotiated mapping licences, assembled the media content, distributed the content via a podcast and developed a web site to enable downloading. Managing the copyright aspect was a significant component of the project. The end product is an enhanced podcast that provides visitors to Sydney (and non-visitors on their desktop computers) with just over an hour and a quarter of commentary, imagery, mapping and navigation instructions that allows them to spend 2.5 informative hours exploring the engineering heritage of the Rocks area. Using the podcast format is a way to reach the music-savvy audiences who already download music to their devices, which in the longer term may help reach younger audiences. It also provides an opportunity for non-music-savvy heritage consumers to discover the benefits of mobile media players.

11. ACKNOWLEDGMENTS

Thanks to Michael Clarke in collaboration of this project. Thanks to Nigel Helyer (SonicObjects) for the background audio included in the podcast. Thanks to voice over talent, Gabrielle Rogers. This project was supported by a grant from the Faculty of Engineering, UNSW. We also acknowledge the support of the Heritage Branch of the Institute of Engineers, Australia. We gratefully acknowledge the support of the institutions that granted access to use the images and mapping data used in the podcast (State Library of NSW, State Records NSW, Sydney Harbour Foreshore Authority, Powerhouse Museum, Australian National Maritime Museum, UNSW Press, MapData Sciences Pty Ltd and Department of Lands NSW).

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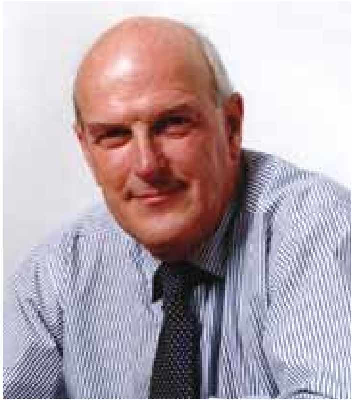
Keynote Speakers

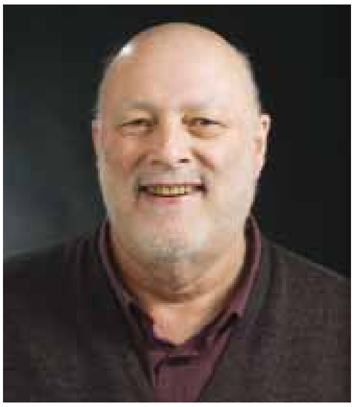


Sir Neil Cossons

Does the Engineering Heritage Matter?

Sir Neil Cossons retired in 2007 as Chairman of English Heritage, the United Kingdom Government's Principal Adviser on the historic environment. Previously, from 1986 to 2000, he was Director of the Science Museum, London – the National Museum of Science and Industry – and, from 1971, the first Director of the Ironbridge Gorge Museum. A pioneer in the field of industrial archaeology, he has spent most of his life engaged in the preservation and conservation of the engineering and industrial heritage. He was awarded the President's Medal of the Royal Academy of Engineering in 1993, the Maitland Medal of the Institution of Structural Engineers in 2002, and is a Companion of the Institution of Electrical Engineers and the Royal Aeronautical Society.

Today Neil Cossons is Chairman of the Council of the Royal College of Art – Britain's only post–graduate college of art and design – and advises internationally on heritage policy and management.



David Dolan

The Engineer as Landscaper and Cultural Warrior

David Dolan has been Professor of Cultural Heritage at Curtin University, Western Australia, since 1995. He is now Vice-President of the National Trust (WA), having been its Chairman from 2001–07. He has served on the Heritage Council of WA for nine years including stints on its Development Committee and Register Committee.

David was previously Manager of Collection Development and Research at the Powerhouse Museum in Sydney. He has been actively involved in community museum and heritage work, as author of numerous reports, conservation plans and interpretation strategies. He has been a Director of AusHeritage, and served on the Board of the Australian Prospectors and Miners Hall of Fame. He is currently on the Maritime Archaeology Advisory Committee of the Western Australian Museum, and the Golden Pipeline Council of the National Trust. For five years he was a Director of the Australian Council of National Trusts.

David has studied and taught history of art and architecture, heritage and museology, and his doctorate is in history and philosophy of science. He has been an invited and keynote speaker at history, heritage and museum conferences in Australia, England, Germany, Hong Kong, New Zealand, and the USA, also publishing in professional journals in several of those countries plus Canada. In 2006 he taught masterclasses at UNESCO in Paris for the "Sharing our Heritages" exchange programme between four Australian and four European universities.

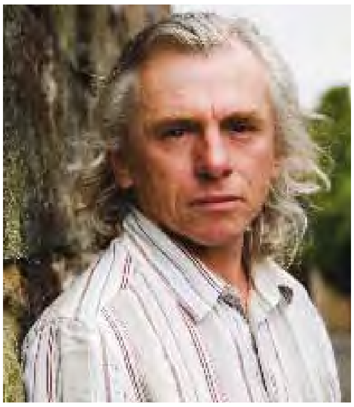
Dr Robert McWilliam

The Prime Movers of Historical Change

Dr Robert McWilliam has degrees in engineering and business from the Universities of St. Andrews, Leeds, Western Ontario and Reading. He is a Chartered Civil Engineer and a Fellow of the Institution of Engineers and Shipbuilders in Scotland. His other credentials include Chartered Membership of the Institute of Logistics and Transport, a Diploma in Town Planning from Edinburgh College of Art and Life Fellowship of the Royal Society for the encouragement of Arts, Manufactures and Commerce.

His career in engineering began three days after leaving high school in Fife, Scotland, as the junior member of a road survey team. Ten years later he was the youngest Area Road and Transport Engineer in the Scottish Office. In a further ten years he was the youngest Industrial Advisor to the UK Monopolies (now Competition) Commission which was followed by various engineering projects for the energy, transport and construction industries.

Thirty-seven years after leaving high school he had ceased to be the youngest anything – but marked his return to the academic world at the National Museum of Science and Industry in London with a successful PhD thesis on the evolution of standardisation during the 20th Century. He wrote the official centenary history of the British Standards Institution and continues to edit work on the development of engineering equipment, the history of construction and biographies of individual engineers. He chairs the editorial panel for the Biographical Dictionary of Civil Engineers in Great Britain and Ireland. He is a Trustee of the Construction History Society and the Motorway Archive Trust and is Technical Secretary of the panel for Historical Engineering Works of the Institution of Civil Engineers.



Paul Davies

Managing Active and Redundant Industrial and Engineering Heritage Sites

Paul Davies is a Heritage Architect working mostly in NSW and Tasmania who has specialised in heritage and conservation projects over the last twenty years. He has a practice based in Sydney with ten staff. He has had a focus on industrial heritage since writing an undergraduate thesis on NSW railway architecture that was awarded the NSW University thesis prize. Since that time Paul has studied, recorded, restored and adapted industrial sites including hop kilns, hydro sites, power stations, fortifications, light houses, railway sites, water reticulation sites, gas works, maritime sites and shipyards and rural and farm sites. He has also undertaken many heritage studies, both thematic, such as the Tasmanian hydro power system, and regionally based, currently completing the Campbelltown heritage study in Sydney.
The thematic studies have specialised in industrial and engineering heritage.

Paul works on a range of other heritage places and is currently restoring St David's Cathedral in Hobart, is designing new school facilities in Sydney and has just completed the conservation management plan for Goat Island in Sydney Harbour.

An area of particular interest is the consequences of identifying and heritage listing places and how that affects the use, management and potential adaptation of places of significance.

Paul also provides advice to government agencies on their heritage properties and has recently been a Design Juror on major heritage adaptation projects. He regularly appears as an expert witness in heritage matters in appeals courts.

Dr Wayne Johnson

Sydney's Darling Harbour: Two Centuries of Industrial Development, Decline, Transformation and Interpretation

Dr Wayne Johnson is the Senior Archaeologist in the Heritage and Design division of the Sydney Harbour Foreshore Authority; the NSW State Government body which owns and manages much of the Sydney foreshore. The Authority's Heritage and Design division is responsible for the adaptive reuse of significant heritage sites such as The Rocks and Darling Harbour, as well as former industrial sites such as White Bay Power Station (1912), numerous wharves and warehouses (dating from the 1820s), the archaeological remains of Dawes Point Battery (1791–1925) and many other associated industrial remains and landscapes.

Most recently the Authority transformed the former Caltex oil storage facility at Ballast Point (1929) into a park, retaining and interpreting industrial features in the landscape design. Previously he was responsible for the conservation and interpretation of industrial heritage at the former Eveleigh Locomotive Workshops (1886) which had been the subject of a major adaptive reuse project by the Authority in the late 1990s. In 2008 Wayne co-authored the book *A History of Sydney's Darling Harbour* which examines the industrial development of Sydney's major port facility from 1810–1970; its demise and rebirth as part of the 1988 Australian Bicentenary celebrations, and more recently the efforts to interpret its industrial history.

Wayne is also the Curator of The Rocks Discovery Museum, itself an adaptive reuse of an 1850s sandstone warehouse. Between 1984–88 he developed exhibitions for the Powerhouse Museum on steam-powered technology, including the museum's 1785 Boulton and Watt beam engine. Following this he worked with the NSW Heritage Council as the Department of Planning's Archaeologist, during which time he served on the National Trust's Hunter and Newcastle Region Industrial Committee, and currently serves as a member of the NSW National Trust Industrial Heritage Committee.

Duncan Waterson

Sir Thomas McIlwraith (1835–1900) Engineer, Entrepreneur, Politician

Duncan Waterson is Emeritus Professor of History at Macquarie University, Sydney. He was born at Matamata, New Zealand, in 1935 and was educated at Matamata College and Auckland University College where he graduated with first-class Honours in history.

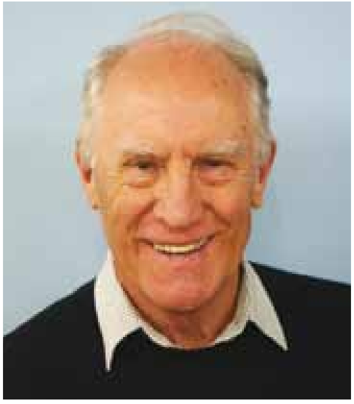
Between 1961 and 1963 he was a Research Scholar in History at the Research School of Social Sciences at the Australian National University, Canberra. Completing his PhD in 1964, he lectured at Monash University, 1964–77, before becoming Professor of Modern History at Macquarie University.

In 1970 Professor Waterson was a Corporation Fellow at Harvard University and in 1988 Visiting Professor of History at Beijing Foreign Studies University. His teaching has been in the fields of Australian, New Zealand, migrant, Scots and political history, and also concentrating on the supervision of Honours and post–graduate students. He retired in 2001 but continues to write, supervise and lecture.

Waterson's major works include a History of the Darling Downs (Queensland), a short biography of Sir Thomas McIlwraith, several pictorial histories of Queensland and Sydney as well as three Biographical Registers of the Queensland Parliament, thirty entries in the *Australian Dictionary of Biography*, several for the *New Zealand Dictionary of Biography* and the *Biographical Dictionary of the Australian Senate*, as well as several other articles in diverse topics.

Since 1989 Professor Waterson has been a regular visitor to Turkey where his father fought with the 1NZEF in 1915. He is overseer of a large ARC-funded research project translating Turkish Archival sources into English for publication.

In 2001 his retirement was marked by a Festschrift, "From the Frontier " in the *Journal of Australian Studies*.



Euan McQueen

Heritage and the Modern Railway

Euan McQueen is of Scots and Dunedin stock. The first two generations of his New Zealand family were engineers with Kincaid and McQueen, based in Dunedin.

The next two generations veered toward the social sciences, and Euan has a Master's degree in geography from Victoria University, in Wellington. After excursions into high school teaching and the public service, he returned to Victoria as a staff member from 1963 to 1969. He then joined the then New Zealand Railways, where the next 19 years were spent in planning, instituting change, and nine years in senior management.

A short spell followed as CEO of the Queen Elizabeth II National Trust, a trust committed to the conservation and protection of open space on private land. Then followed 18 years (so far) as a portfolio person in Wellington, with roles as diverse as Regional Councillor (eight years), independent commissioner for Resource Management Hearings (14 years), member of a regional medical ethics committee (five years), a community representative on the regional primary health care organisation, and a variety of consulting roles, many involving transport.

Behind all this lay the constant role of Chair of the Rail Heritage Trust of New Zealand, 1991 to date, and a deep and long-term interest in railway history, especially that of New Zealand. Alongside that, general interest has been a special and growing commitment to the "small railways": the industrial railways, often narrow gauge, that served coal mines, forestry, and factories in the days before large trucks, forklifts, and other modern means of handling products were available. This interest has now extended to the construction of an 80-metre, 610-mm gauge railway at a secret location in the Wairarapa, where it is used for handling firewood, pea straw, and other freight to be found in maintaining a large garden.

He has published two books about aspects of New Zealand railway history, and has written many articles about both railways and, in his university days, New Zealand economic and transport geography. He has been known to enter into public debate about proposed changes to transport policy, and has given numerous talks to a range of interest groups about all manner of topics, but usually with a transport theme.

Retirement lurks near a distant horizon. It will be occupied by fewer jobs, and more time on sorting papers and photographs that have been accumulated over the last half century or more, with the aim of leaving a reasonably coherent body of knowledge about railways, and other forms of transport, and their place in New Zealand's development over that period.

Presenters

David Beauchamp

John Harry Grainger, Engineer and Architect

David Beauchamp was born in Auckland New Zealand in 1936. He spent much of his boyhood in Picton before going to Canterbury University College (CUC) where he completed a BE (Civil) in 1958. In his final year at university, he captained the CUC athletic team that won the Lovelock Relay in Dunedin – the relay held each year to commemorate Jack Lovelock winning the 1500 metres at the 1936 Berlin Olympics.

After working for the New Zealand Ministry of Works in Fiji and Wellington he came to Melbourne at the end of 1963, initially working for Civil and Civic and then for John Connell and Associates until 1969, apart from one year in London working for Mott Hay and Anderson in their bridge design section.

In March 1969 he started his own structural and civil consultancy practice, designing the structures for a wide range of buildings, while working with many of Melbourne's leading architects. More recently he has specialised in forensic and heritage engineering, writing reports on building failures and on historic structures, including the Murtoa Grain Store, the Victorian Houses of Parliament, the world heritage-listed Exhibition Buildings, Princes Bridge, Barwon Heads Bridge and the 1867 Ellerslie Bridge.

In 1973, David Beauchamp, George Tibbits and Miles Lewis were awarded the RAIA (Victorian Chapter) Robin Boyd Environmental Medal for their report "Urban Renewal Carlton an Analysis". This report helped stop the Housing Commission from demolishing 80 hectares of the historic inner-Melbourne suburb of Carlton.

He was the first Chairman of the Council for the Historic Environment, an inaugural member of the Victorian Heritage Council and a member of the National Trust's Bridges Committee.

Currently he is a member of ICOMOS, the APT, the Institution of Engineers Australia, the Institution of Civil Engineers, and Chair of Engineering Heritage Victoria.

Trevor Butler

Port Craig Viaducts Conservation Plan

Trevor Butler leads a team of consultants at Frame Group Ltd that specialise in heritage asset management and recreation facility development throughout NZ. This includes work on many iconic historic assets and development in high-profile natural heritage sites. He has a BE(Hons)Civil and an MBA and has been made a Fellow of IPENZ in recognition of his work in the application of appropriate engineering practice in sensitive outdoor environments. Mr Butler has worked in the planning, design and management of restoration work on several heritage bridges in remote sites, including recent work on the Hapuawahenua railway viaduct near Ohakune, Bertrand Road suspension bridge near New Plymouth, as well as the Port Craig viaducts in Southland. He has particular interest and experience in timber preservation and steel corrosion protection and has been successful in developing appropriate, cost-effective methods for the restoration of heritage assets.

Andrew Cleland

Refrigeration: underpinning the New Zealand economy for over 125 years

Dr Andrew Cleland is Chief Executive of IPENZ. In this role he provides leadership for the engineering profession in addressing a wide range of issues. These include registration, handling complaints, codification of good engineering practice, public policy, and engineering education. He has played a leading role in the engineering profession and its important contributions being recognised better in Government. Prior to taking up his current role in 2000 he was an engineering academic with research interests in energy, refrigeration, and food process engineering. He has been recognised internationally for research in food and refrigeration engineering and holds Fellowships in IPENZ and the Royal Society of New Zealand.

Rachael Egerton

Heritage Management at the Port Craig Sawmill Complex: Successes and Challenges

Rachael Egerton has been working for the Department of Conservation as a technical advisor on historic heritage since 1995. My work includes conservation planning, recording and assessing the value of sites, researching history, advising on interpretation and public information, training and mentoring staff, technical conservation advice, and promoting protection and conservation of heritage. I have been privileged to work on a wide range of heritage across Fiordland, Southland, Stewart Island, and the NZ Subantarctic islands. Sites I have been involved in managing include pre-historic and historic archaeological sites, industrial ruins, mining remains, historic tracks, tramways and roads, buildings and structures, all with their unique conservation challenges. Management of many of these places involves working closely with Ngai Tahu, community groups, and partners such as NZHPT and University of Otago. Like many heritage professionals, I often spend recreation time or holidays visiting heritage places and museums, in NZ and overseas. I am currently a member of the Professional Historians Association of NZ/ Aotearoa, NZ Historic Places Trust, Australasian Society of Historical Archaeology, Federation of Graduate Women of New Zealand, and NZ Archaeological Association (NZAA) for which I am currently a council member. I am also the Southland District File Keeper for the NZAA.

John Fitzmaurice

History of Auckland Wastewater and Mangere Wastewater Treatment Plant

John Fitzmaurice has the right credentials to tell the story of Auckland's wastewater and the Mangere Wastewater Treatment Plant, as his first job as a young engineer was with the Auckland Metropolitan Drainage Board at the time of the Browns Island controversy.

The hiatus in implementing the Mangere scheme enabled him to apply for and win a Fulbright Travel Grant and obtain a Master's degree in sanitary engineering from Harvard University in Massachusetts. On return he spent 12 years with the Board, rising to the position of Design Engineer (Special Works), responsible for administering all contracts for the Mangere Wastewater Treatment Plant and all pumping stations in Stage 1 of the Manukau Scheme.

Subsequently, practising as Steven Fitzmaurice and Partners, John designed or supervised a number of municipal sewerage schemes throughout New Zealand. John became an Executive Director of Beca Engineering when the practice merged in 1989.

On retirement John served as a Deputy Commissioner of the Environment Court for six years. He is currently a member of the Audit Group for Project Manukau, responsible for overseeing compliance with the resource consents for the recent Mangere Treatment Plant upgrade. He is a member of the Auckland Engineering Heritage Chapter Committee.

Don Fraser

American Bridges in New South Wales 1870 – 1932

Don Fraser retired from the University of NSW in 1992 where he was an Associate Professor in Structural Engineering.

He began his engineering career in 1949 as a cadet Civil Engineer with the New South Wales Government Railways.

After 15 years of practical experience with Government work and with structural consultants he joined the University of NSW in 1968 and gained his PhD in 1975.

For more than two decades he has taken an increasing interest in engineering history and heritage and has served a term as Chairman of the Institution of Engineer's National Committee on Engineering Heritage, now Engineering Heritage Australia.

His specialist topic is the history of bridges, particularly in New South Wales, and the interaction with political and social history.

During recent years as a Consultant he has prepared many bridge reports for State Rail, The Roads and Traffic Authority, Heritage Consultants plus Plaquing Nominations.

He has written a number of papers and two books, and given many talks on this subject at conferences (local and international), historical societies and community organisations such as the U3A movement.

John Gibson

Remnants of Early Hydraulic Power Systems

John Gibson graduated from UNSW with a science degree, and later went on to study metallurgy. In 1973 he took a position as lecturer at Sydney Teachers College. The College was later amalgamated with Sydney University where he held positions of Senior Lecturer and Head of Department within the Faculty of Education and taught engineering studies and materials science to prospective technology teachers. In 1989 he graduated with a Masters degree in historical archaeology from Sydney University.

John has been involved in a number of conservation studies in the mining areas of Lucknow, Gulgong, and Prospect (Boral), and industrial sites such a Goodyear (Camelia) and Hartley. He joined the Engineering Heritage Committee of Engineers Australia in 2001 and was secretary in 2002/3.

Owen Graham

The Otago Central Rail Trail: Preservation of heritage sites through development for visitor use

Owen Graham is the Otago/Southland Area Manager for the New Zealand Historic Places Trust (NZHPT). Prior to joining NZHPT in July 2007, Owen worked for the Department of Conservation in Otago as the Conservancy Supervisor for Historic Heritage and Recreation Planning. Owen has a BA (Geography) and a Post Graduate Diploma in Tourism both from Otago University, Dunedin, New Zealand. He is currently undertaking further research for his Master of Tourism, focused on Dunedin as a Heritage City.

As Otago Recreation Planner with DOC, Owen was Project Manager from 1994 through to 2006 for the re-development of the 150km former Otago Central branch railway in to New Zealand's first Rail Trail. He was also the Executive Officer for the Otago Central Rail Trail Trust during the same period and raised funds to develop and promote the Rail Trail and fostered community engagement with the project. During the development of the Rail Trail, Owen undertook or commissioned several visitor and community benefit surveys. Owen produced a book in 2004 about the Otago Central Rail Trail titled *From Steam Trains to Pedal Power* and maintains his involvement with Rail Trail communities through his 10-year involvement as an organiser for the annual Rail Trail duathlon.

David Hamilton

Early Water Races in Central Otago

David Hamilton is a consulting engineer based in Dunedin. Main areas of activity are river and flood control and irrigation including small dams. David went to the University of Canterbury and was in the first cohort of agricultural engineers taught by Professor John Burton, Terry Heiler and Walter Boughton. He commenced work with the Ministry of Works and Development in 1969 in Otago and worked on the Lower Waitaki Irrigation Scheme and a number of the Central Otago irrigation systems. Two years on water supply in Western Samoa and then four years with the Hawke's Bay Catchment Board saw David return to Otago as Chief Engineer to the Otago Catchment Board in 1983. With local government reorganisation in 1989, David was appointed Director of Operations / Technical Services with the Otago Regional Council. David has been Otago Branch Chairman of IPENZ and was Chairman of the IPENZ Technical Group on Water. In 1991 he was made an IPENZ Fellow. In 1997 David set up his own small consulting engineering business and provides services to a number of irrigation companies, local authorities and mainly rural clients primarily in Otago. He enjoys Central Otago and is now an irrigator himself on a lifestyle block near Alexandra with water delivered by gravity via old mining water races and 75-year-old dams.

Bill Harvey

Two papers within a single presentation time
1. Interactive Analysis of Arching Masonry Structures
2. Monitoring and Measuring Historic Masonry Structures

Bill Harvey wanted to be a bridge engineer from the age of seven. He studied at Leeds and worked on a number of bridges, including Humber, before taking up an academic career in 1977. Since 1981 he has worked on arch bridges, with a broadening interest in historic structures generally. He set up his consultancy in 2000. Since then, his work has encompassed inspection, assessment, monitoring and refurbishment of structures. He has written a guide to Arch Bridge Assessment for the International Federation of Railways (UIC) and numerous reports for Network Rail in the UK. Bill continues his research work. In 2006 he tested a full scale skew arch bridge and from that developed fresh concepts on arch behaviour leading to new analytical techniques. The measurement techniques used there were developed in monitoring bridges where it was necessary to measure movement under live traffic. He has also developed techniques for measuring movement where datums are difficult to provide. Bill has lectured widely in universities across Europe and further afield. He is deeply concerned about the lack of fundamental understanding of structural behaviour exhibited in much analytical work in the modern world.

Peter Holmes

Archaeology and the Industrial Landscape: 21st Century Adaptive Redevelopment Confronts 19th Century Industrial Heritage

Peter Holmes received his BA in anthropology and archaeology in 1996 from the University of Auckland and his MA in archaeology in 1998 at the University of Auckland, New Zealand. Since then he has accumulated over 10 years archaeological experience which includes report preparation, laboratory analysis, conservation and fieldwork in the Midwest and Mid-Atlantic regions, from upstate New York to Florida. In addition he has an extensive background in historical research as well as historic and prehistoric ceramics analysis and research with the presentation of several research papers. Projects have included extensive heritage survey and assessment for residential and commercial developments, highways, pipelines and airport extensions across the United States, New Zealand and Australia. Since joining SKM in Melbourne in 2008 as a Senior Historical Archaeologist, he has completed several heritage registered projects involving survey, assessments, excavations and permits for several major rail and water infrastructure redevelopments and upgrades in Victoria.

Kevin Jones

Aerial photographs and the record of agriculture and engineering in Otago

Kevin Jones is a Wellington-based Archaeologist specialising in aerial photograph interpretation, archaeological site survey and site significance, regional studies and World Heritage in the Pacific. Recent work has included a report on co-management between the Department of Conservation and Ngati Whare over the Whirinaki Conservation Park.

Paul Mahoney, Tom Williamson

Telling Engineering Heritage Stories

Paul Mahoney is Manager Historic Heritage in the Head Office of the Department of Conservation. The role involves developing heritage programme systems and standards, and providing technical information and training to staff. A current initiative is fostering the development of twenty Icon Sites that tell engaging stories of Kiwi identity.

The Department manages as many as 150 sites and structures throughout New Zealand with engineering heritage values, including 12 of the Icon sites. These include some of New Zealand's most popular engineering heritage sites like North Head fortifications, Karangahake gold mines, the Bridge to Nowhere and the Central Otago Rail Trail.

Paul trained as a Civil Engineer and has worked professionally in heritage since 1981. He also continues a volunteer involvement that started in 1967. He has presented conference papers on a range of engineering heritage topics including: roads, horse tracks, bush tramways, railway infrastructure, bridges and the timber industry.

Paul is concerned at the low uptake of heritage values in society, and believes that focusing on improved communications will bring long-term benefits. For any heritage initiative to succeed, both short-term and long-term, it must include a strong element of effective engagement with the public. A challenge is that this area of work is not familiar territory to most heritage enthusiasts.

Peter Lowe

Engineering Archive – Preservation and Prospects

Peter Marquis-Kyle

Queensland's timber and iron lighthouses: 19th Century colonial innovation

Peter Marquis-Kyle grew up in Brisbane, studied architecture at the University of Queensland, and graduated in 1975. Since 1978 he has specialised in conserving historic buildings and places. He was a Partner in a specialist conservation architecture practice, which he left in 1998 to establish a one-man practice based in Brisbane.

He has undertaken many conservation studies and projects on a wide range of building types, from slab huts to cathedrals, for private, corporate, community and government clients, with budgets ranging from almost nothing up to A$200 million. Since the '70s he has seen conservation work become a mainstream undertaking, as heritage protection laws have been enacted in the various Australian jurisdictions and as professional standards have improved.

With Meredith Walker he was commissioned by Australia ICOMOS to write *The illustrated Burra Charter*, a book that demonstrates and explains good practice in conservation. The book was first published in 1992, and was expanded and largely re-written after a major overhaul of the Burra Charter in 1999. The current version, *The illustrated Burra Charter: Good Practice for Heritage Places*, published in 2004, has received positive reviews and various awards.

Peter serves as a member of the Queensland Heritage Council and of the Brisbane City Council Heritage Advisory Committee. He has been active in Australia ICOMOS and other professional and community-based conservation organisations. He has particular interests in the care of timber structures, and in interpreting the cultural significance of places to a non-professional audience.

During 2006-2007 Peter inspected, surveyed and reported on the condition and maintenance requirements of 58 heritage listed lighthouses operated by the Australian Maritime Safety Authority. This project awoke a new interest in the historical development of navigation aids in the Australian colonies.

Gavin McLean

There's Naught to Fear for the Port of Oamaru

Gavin McLean is a Senior Historian at the History group of the Ministry for Culture and Heritage, for whom he co-edited *Frontier of Dreams*, a guide to local history and a history of our governors and governors-general and is currently finishing a co-written history of quarantine and is researching a history of the prime ministership. An Otago PhD graduate, he has written extensively on aspects of the province's past, as well as on New Zealand business and transport history. His recent publications include *Kiwitown's Port: The Story of Oamaru Harbour* (2008), *The Penguin Book of New Zealanders at War* (co-edited with Ian McGibbon, 2009) and *A Voice for Shipping: The New Zealand Shipping Federation Story* (2009). Last week John Key opened his exhibition at the New Zealand Portrait Gallery, 'The Cabinet Makers: New Zealand's Prime Ministers.'

Rob Merrifield

A Centennial Review of the North Island Main Trunk Railway: Geology of the West-Central North Island and its Influence on Transport Development

Rob Merrifield comes from Canterbury originally, where he graduated from the University of Canterbury. He joined the Ministry of Works and Development in Gisborne at the end of 1962, where much of his work was involved in roading in that very difficult region. He worked in Wales and England for some ten years before returning to the Wairarapa. Still mostly working on roads and bridges, in private practice and in local government, he subsequently resumed work with MWD, moving to Roading Division in Wellington in 1982. Since that time Rob has mainly interfaced with local government in an advisory and technical audit role, concentrating on the maintenance of roads and bridges. He introduced the use of statistics as a tool for the overview of trends in expenditure and road pavement condition, and for benchmarking between different authorities. Rob continues to work in this field part-time, for New Zealand Transport Agency.

Rob's interest in railways arose from having a railwayman father. Truly, the railroad ran through the middle of the house; shift work saw to that as it influenced the daily cycle of family life. He joined the New Zealand Railway and Locomotive Society in 1956, taking part in many aspects of its activities and writing a great many articles for its magazine as well as a stand-alone booklet on the Picton-Kaikoura railway. The combination of his professional interests in transport and geology comes together with his private interest in the history of the rail transport industry in his paper for presentation to this conference.

Owen Peake

The History of High Voltage Direct Current Transmission

Owen Peake graduated from Royal Melbourne Institute of Technology with a Fellowship Diploma in Electrical Engineering in 1964. He first worked for the Commonwealth Department of Works on the design and construction of hydro-electric power stations in Papua New Guinea.

On moving to Darwin in 1968, Owen worked in the Electricity Supply Undertaking until the Commonwealth involvement ceased at Self Government in 1978. He transferred to the Northern Territory Electricity Commission until it was absorbed into the multi-utility Power and Water Authority (PAWA) in 1987. He was Chairman of Commission in 1986-1987.

He held several senior management roles in PAWA from 1987 to 1994 then served as CEO until 1997.

Owen then held several senior positions in the Northern Territory Government, specialising in the IT area until retiring in 2002.

In 2000 he spent a year in East Timor working for the United Nations on the restoration and management of electricity and water supply services following the destruction by Indonesian-backed militia in 1999.

During his time with the Northern Territory he was involved in managing the recovery of the electricity supply system following Cyclone Tracy in 1974 and was later responsible for the construction of gas-fired power stations and gas pipelines when the Northern Territory changed from oil to natural gas as its generation fuel in the 1980s.

Owen joined the International Stationary Steam Engine Society in 1989 and became the Australasian Contact in 1995. The Society researches and records stationary and marine steam heritage throughout the world and Owen writes extensively for the Society's publications.

Owen has been involved with Engineering Heritage Australia since 2002, serving on the Northern Division and more recently on the Victorian Division committees. He has also been on the National Board during this time and is currently Chair.

Miles Pierce

Early Electricity Supply in Melbourne

Miles Pierce graduated with a Bachelor of Engineering degree from the University of Melbourne in 1965 having previously obtained a Diploma of Engineering at the Gordon Institute of Technology in Geelong. The majority of his professional career has been with consulting engineers GHD P/L – formerly Gutteridge Haskins and Davey – and for many years he was Principal Electrical Engineer in the Melbourne-based Victorian practice. His experience covers electricity supply infrastructure, industrial and commercial/ institutional power systems, process control and instrumentation and illumination engineering.

Miles has had a long-term interest in engineering and industrial heritage with a particular focus on mechanical and electrical engineering heritage. He is a long-serving committee member for the Institution's Victoria Division, Engineering Heritage Group – Engineering Heritage Victoria – and is currently Deputy Chairman of EHV.

John Porter

Preservation by Operation

John Porter retired in 1993 after a lifetime in the marine industry. After a degree in mechanical engineering at Edinburgh and apprenticeship on the Tyne, he went to sea with Shell Tankers. He then worked in Shell International Marine's Application and Development section and technical management before moving to the P&OSN Co in 1969. There he was involved in the full range of shipowner's technical work – new buildings, major conversions, superintendency, troubleshooting and development. This also involved work as a consultant with other shipowners and the offshore industry. Latterly he was involved with quality control administration, safety certification and inspections with the P&O Group safety audit team. Before retirement and since, he has been active with the Kew Bridge Steam Museum (five original early 19th Century Cornish cycle non-rotative steam pumping engines plus four large rotative units re-erected there) and the Kempton Great Engines Trust (two very large reciprocating pump units plus two turbine units) as a driver, a restorer and a general volunteer. Until recently, he was a Trustee of the Kew Bridge Museum. He has also been active with the Newcomen Society and has written papers and journal articles, given talks and enjoyed visiting many of the world's stationary steam engine sites.

Nigel Ridgway

The Coorong Battery at the Winnecke Gold Mine, NT

Nigel Ridgway graduated from the Whyalla Institute of Technology and the BHP traineeship system with a degree in mechanical engineering 1988. After graduating, Nigel was employed as the Mill Engineer at Western Mining Corporation's Olympic Dam site. He has been employed in the slurry pump and mining industry for 15 years and has an interest in fluid mechanics, tribology and mineral processing. He is currently Operations Manager for a South Australian engineering firm.

Nigel has been a member of the SA Division's Engineering Heritage and History Branch for many years and was Chairman from 2000 to 2006. In this role, he survived many historic engineering plaquings including the Trans Australia Railway, the Barossa Dam, and the River Murray systems. During this time he was also a member of the National Board of Engineering Heritage Australia.

Nigel has represented Engineers Australia on the History Council of South Australia and later became Vice President. He was chosen to be the South Australian representative on the Federation of Australian Historical Societies. Nigel is also a member of the International Stationary Steam Engine Society (ISSES) and has contributed articles on mines and engines to the ISSES Bulletin.

He is a Fellow member of Engineers Australia and has just completed his PhD thesis at the University of Adelaide.

Tony Silke

From the Corporate Dump to a National Resource

Tony Silke started in the New Zealand State Hydro Electric Department in 1954 as a hydro-electric apprentice in Nelson District. This trade background was a good base for his later career in maintenance and operating of power stations and substations.

He commenced his substation maintenance at Kikiwa Substation, the Northernmost 220kV substation in the South Island. He then changed his interest to substation operating at Kikiwa which gave him a good grounding in high-voltage operating.

Tony then promoted through operating in various hydro-electric power stations including Waipapa, Roxburgh and Cobb. He was then promoted to Senior Substation Operator at Haywards, the North Island end of the Inter-Island HVDC Link. This move was in the '60s when the HVDC was new and was rather troublesome technology in its early years.

From Haywards Tony promoted to System Operator at the South Island System Control Centre at Islington in Christchurch. In those pre-electricity market days, System Control managed both the high-voltage South Island electricity transmission system, plus the complex hydraulics of the South Island lakes and power stations. System Control was a specialised career in itself and Tony promoted through various South Island positions.

Transpower decided to integrate the North Island and South Island Control Centres into one management structure and Tony took on the position of Manager of both Islington and Hamilton centres.

This position was then combined with the Wellington System Control Group and Tony was appointed Power System Services Manager in Transpower in Wellington. This time coincided with the first stages of the introduction of the New Zealand Electricity Market.

Tony's academic qualifications include a degree in sociology which he gained as a mature student.

More recently Tony has worked as a Risk Management Consultant for Transpower and has lately worked solely on the setting up and running of GridHeritage.

Jim Staton

Golden Lead – Golden Dreams

Jim Staton is one of few full-time Programme Managers – Historic within the Department of Conservation, (DOC). Jim's area covers the Grey and Inangahua Valleys, home to intensive alluvial and hard rock mining, timber milling and coalmining since the late 1860s.

His interest in industrial relics started with a chance encounter meeting with one Paul Mahoney at the Davidson Locomotive site south of Ngahere in the Grey Valley in 1974, since that time he has been involved in just about all of the major industrial heritage restorations on the West Coast, plus a few others around New Zealand.

Jim provides advice nationally within DOC, and to other heritage advisers on how to treat and restore rusting and rotting things, has provided research material for various publications, identifies relics – or parts of relics, has co-ordinated many heritage volunteer projects and Ilam University Civil Engineering field trips to the West Coast.

Jim is the regional rep for the Rail Heritage Trust of NZ, West Coast and Nelson areas, a member of the NZ Historic Places Trust, (was on the regional committee for 25 years, Chair for three of those years). He is a member of Mainline Steam, The West Coast Mechanical Society (Shantytown), and President of the Westland Industrial Heritage Park.

His hobbies include the restoration of industrial relics, model railways and sawmilling history.

Richard Venus

The Engineering of "Engineering a City"

Richard Venus graduated from the University of Adelaide with a degree in electrical engineering in 1969 and was employed by the Electricity Trust of South Australia (ETSA) for more than 30 years. For eight years Richard was ETSA's Industrial Advisory Engineer and a member of several Electricity Supply Association of Australia (ESAA) and Standards Association of Australia committees. For several years he was Chairman of the ESAA Electrofarming Committee.

Richard acquired his interest in engineering heritage in the late 1970s when he assisted two local authors in researching the history of electricity supply and distribution in South Australia. In 1994 he joined the South Australian Division's Engineering Heritage Branch and became its Chairman in 1997.

Over several years Richard has compiled a number of comprehensive guides to field trips organised by the Heritage Branch along with engineering heritage plaquing nominations and in February 2008 he was presented with an Award of Merit for Engineering Heritage from Engineering Heritage Australia. In October 2009 he completed an innovative visitor guide to the engineering heritage of the City of Adelaide published by the South Australian Division to mark EA's 90th anniversary year.

Richard is currently working towards a Master of Archaeology degree at the Flinders University of South Australia where he completed a Bachelor of Arts degree in 1977 (and still has his old student number). He is also striving to complete a history of the South Australian engineering company Southcott Pty Ltd which will have its 125th anniversary in 2011.

Ian Walsh

Waitaki Dam – 75 Years On

Ian Walsh is a civil engineer who studied initially at Canterbury and later pursued further studies in geotechnical and dam engineering at the UNSW in Sydney. He is employed as technical services manager with Opus International Consultants based in Dunedin, and he has a long involvement with water resource engineering covering irrigation, hydro-electric development, and municipal water supply.

Ian has a specific interest in dam design and dam safety management, and it is in this context that he was active over a period of several years during the early 1990s on the refurbishment of several aspects of the Waitaki dam. In seeking to understand the mindset of the original designers and constructors of the dam, he has needed to grasp the changing state of technical knowledge that has occurred since the 1930s, particularly in fields such as rock mechanics and seismology.

Ian is currently design leader for several small hydro developments, and he provides technical assistance to regulators administering the new statutory dam safety regime under the Building Act. He also leads the provision of risk management services for a range of clients covering infrastructure asset development, asset management, and service delivery activities.

Tom Williamson, Paul Mahoney

Telling Engineering Heritage Stories

Tom Wilkinson began working in industrial documentaries over 40 years ago, directing his first film just two years after starting as a tea boy in the sound department of a small studio just outside London.

Subjects ranged from the Building Research Station to making weighing scales, recruiting engineers for the army to designing postage stamps, a new type of industrial fastening to beer kegging machinery – and for one glorious film, pubs, the length and breadth of Britain … plus two films for the Ministry of information about Bahrain and doing business there.

Following visits to New Zealand to make a film for Caltex, Tom brought his young family over and joined the National Film Unit (NFU) in Wellington as head of production. Five years of battling with bureaucrats sent Tom back to actually making films, which he has been doing ever since.

During the last ten years of NFU before it was sold, subjects have ranged from the a record of the construction of the synthetic petrol plant at Motonui, to a five-part series on the science of Antarctica, "The Big Ice".

Since NFU closed in 1990, Tom has been an independent, making videos both to client requirements and self-initiated. Subjects have ranged from the deep-sea fishing industry to a six-part series on scientific research projects for CRIs and universities, in association with the late lamented eTV.

The digital video revolution has allowed Tom to indulge in his long-held interest in industrial and engineering history. Several videos have been produced about heritage sites around New Zealand in association with the Department of Conservation. Others have been made with grants from trusts ("New Zealand Flax – A Fortunate Fibre", the case study for the conference), "Bottled Lightning", about the Reefton hydro station, "The Lyttelton Timeball Station" for NZHPT.

Totally self-financed have been a series of productions about traction engines. In the pipeline are new productions about sawmills, the grain industry, early ways of harnessing and using power … never a dull moment!

Matthew Churchward

Gas Engines in Victorian Industry, 1870 to 1950"

Matthew Churchward originally trained in mechanical engineering, later undertaking a Master's degree examining the development of mining machinery manufacturers in Victoria during the 19th Century.

In 1989-90 he undertook the Victoria Steam Heritage Survey for Museum Victoria, researching the history of steam power in Victorian industry and completing extensive fieldwork to document and record some 2,000 examples of historic steam equipment throughout the state. He has also worked for various government departments as an Industrial Heritage Consultant.

Since 1994, he had been employed as a curator in engineering and transport with Museum Victoria undertaking research, exhibition development, collection development and documentation, machinery restoration and conservation projects. For the past 15 years he as been a member (and current Chair) of the National Trust (Vic) Industrial History Committee and has been actively involved on the steering committee overseeing the Victorian Timber Bridges, Metal Bridges and Concrete Bridges Studies, developing the bridges database used for the studies and helping to edit the book *Wooden Wonders*. Current research interests include Australian mining, engineering and transport history with an emphasis on Victorian transport infrastructure, horse-drawn vehicles, immigrant shipping and local engineering and manufacturing history. His research for this paper has been undertaken as part of a wider study into various forms of industrial power utilised in Victorian industry from the mid-19th to mid-20th Centuries.

Daniel Woo, PhD

Sydney's Birthplace - walk and podcast

For the past decade, Daniel Woo has led human computer interaction teaching and research in the School of Computer Science and Engineering at the University of New South Wales. User experience and design are at the core of his research and development activities.

He has worked on a variety of research, development and teaching projects with the National Institute of Dramatic Art (NIDA), Schools of Chemistry, Surveying and Spatial Information Systems (SSIS) and Industrial Design at UNSW and has consulted on usability and design for Kahootz 3.0, SBS First Australians, UNSW Library, New South Global and the Independent Living Centre. In 2003, he was part of a successful ARC Linkage grant, AudioNomad, under the inaugural Synapse Initiative; a collaboration between the Australian Research Council (ARC) and the Australia Council for the Arts to bring artists and scientists together to form novel collaborations. In 2009, in conjunction with SSIS, Vision Australia and an industrial designer, he has been awarded an ARC Linkage grant to investigate and design navigational technologies for the blind and visually impaired.

Since 2000 he has established formal testing and teaching infrastructure to support usability evaluation and software design of user interfaces. He continues to manage, create and design software systems from web through to iPhone. He has been working with mobile devices and media for almost two decades including experience in audio, speech technologies, photography and video.