The 75-Miles Dam south of Warwick: the World's Oldest Concrete Arch Dam

by H. Chanson

Submitted 26 November 1998

Since early European settlement in Australia, the coastal and continental development of the country has been coupled with the availability of water supply. Limited water supply is available on the Australian continent because of the dry climate. The median annual rainfall is less than 400 mm over 60 per cent of Australia Rain usually occurs during a wet season, associated with intense falls and the rest of the year is very dry.

During the first part of the 19th century, the Europeans built small dams and weirs for water supply.[1] The design was based on British experience. Most structures were earth embankments with a clay puddle core. The largest dams included Yan Yean near Melbourne in 1857,[2] Kirks at Ballarat, Victoria in 1862, Beales, Ballarat, 1863, Enoggera, Brisbane, 1864, Spring Gully, Bendigo, Victoria, 1868, Hope Valley, Adelaide, 1872, and Gold Creek, Brisbane, 1885.

Later, more sophisticated structures were completed, including buttress dams, multiple-arch walls and thin-arch dams. Most gravity dam designs were influenced by the French masonry dams built in the 1860s although nearly all Australian gravity structures were concrete wails.[3] Major exceptions were the Parramatta arch dam completed in 1856 and heightened in 1898 and the subsequent series of arch dams built in Australia, the second arch dam being built in 1880 near Warwick, Queensland: the 75-Mile Dam.[4] It is the purpose of the paper to highlight the innovative engineering features of the structure and the design soundness.

History of the Railway

The 75-Mile Dam and its reservoir, the Gorge Tank, were built to supply water for the steam locomotives on the Warwick-Stanthorpe extension of the Southern & Western Railway. Steam traction ended in the area in 1969 apart from touristic steam excursions.[5]

The dam is located above the railway line in the catchment of Mineral

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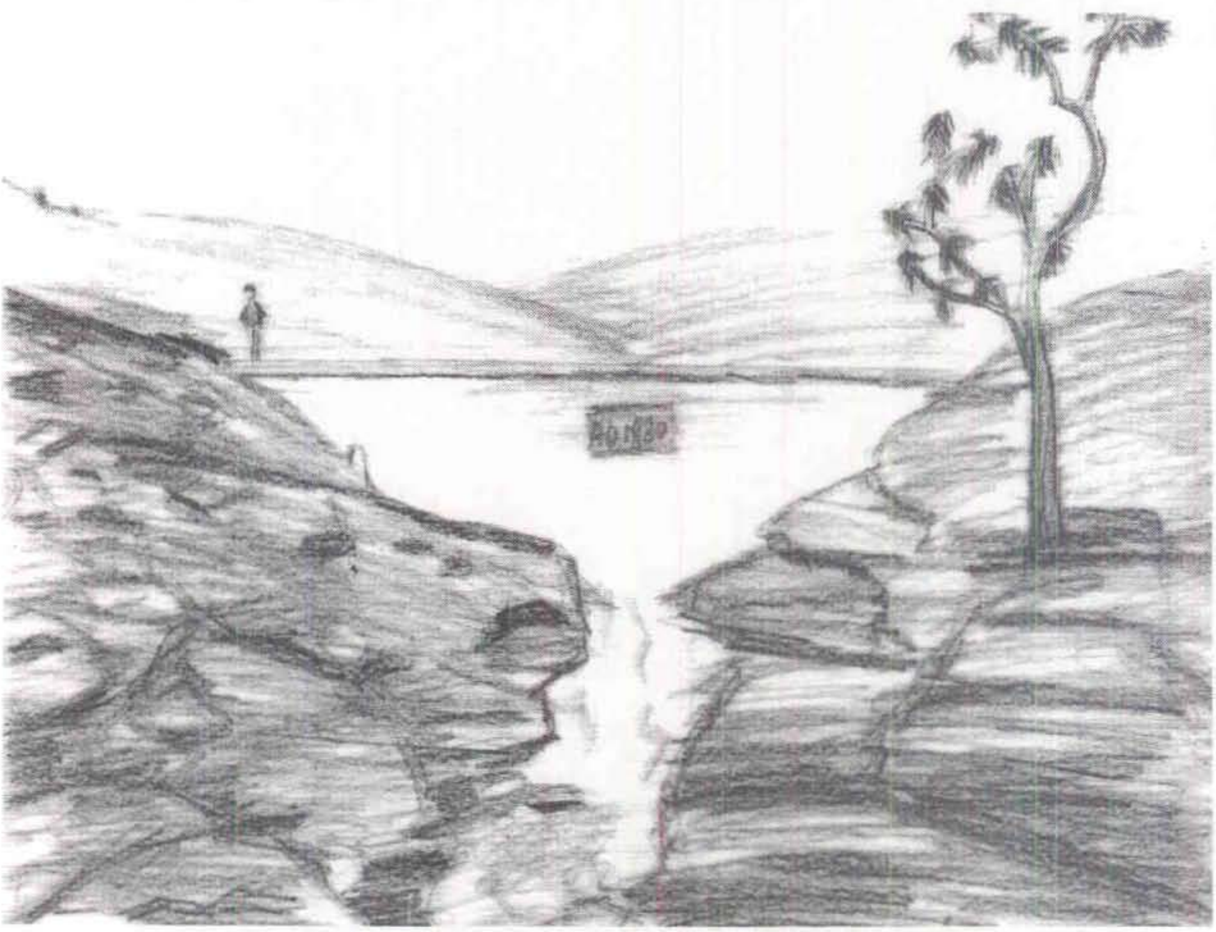
Creek (but not on Mineral Creek itself). The dam wall is sometimes called the 'Ravine Dam'. The reservoir location is 74 miles 77 chains, basically 75 miles, from Toowoomba (via Drayton) between Silverwood and Cherry Gully stations. Today the reservoir is located 279-km from Roma Street station, Brisbane, on the Southern Line.

The Southern & Western Railway was the first railway system built in Queensland. The surveys of the extension from Warwick to Stanthorpe took place in 1873 and 1875-77.[6] The reservation for the dam was probably made during the working survey. Construction of the extension line was approved by parliament on 7 August 1877. The contract was awarded J. & A. Overend for Section 1 to Cherry Gully[7] and J. Garget for Section 2.[8] Construction commenced in May 1878. Earthworks and the concrete culverts were completed in July 1879. Major works included two tunnels: the Gorge tunnel (also known as the Cherry Gully tunnel or simply Big Tunnel), lined with concrete, and the Dalveen tunnel, lined with concrete and brick located further south. The Gorge tunnel was nearly completed on 20 March 1880. About 800 people of all kinds were employed in 1879 and 1880. The line opened in two stages. The 38-miles line to Cherry Gully was opened on 8 December 1880 and the extension to Stanthorpe was opened on 3 May 1881.[9]



Hand-drawn sketch of the 1880 dam, made from an old photograph (courtesy of Ms Chou Y.H.)

Dam construction

The dam construction took place in two stages. The first dam was built in 1879-1880 and completed in 1880.[10] It was designed by Henry Charles Stanley (1840-1921),[11] Chief Engineer for Railways, Southern Division and subsequently the entire colony, 1872-73, 1875-1901. It was built at the same time as the Gorge railway tunnel.[12] The dam was a concrete arch wall.[13] The concrete aggregate came from the tunnel excavations. The maximum dam height above foundation was 5.04 metres and the crest length was 24.5 metres. There is conflicting information on the reservoir capacity: 1,295 cubic metres [45,673 cubic feet, 285,000 Imperial gallons][14] or 1,818 cubic metres [400,000 gallons].[15] The original spillway was an overflow over the entire crest. The dam was equipped with a scour outlet of 12 inch [305 mm] internal diameter and a pipe outlet of 3 inch (76 mm) diameter. A pipeline feeds a water tank located beside the rails.[16]

In 1900-1901, the dam was heightened to 8 to 10 metres under the supervision of Stanley.[17] The enlargement included the addition of a vertical uppermost section on the top of the first wall and the addition of three downstream buttresses.[18] The cost was £393. All the works (buttress and dam heightening) were made of concrete. The curved wall has now a 30 metre long crest and the arch radius is unchanged. Each buttress has a 1.1 x 2.1 square metre cross-section. The dam is equipped with an overfall spillway (24 metres long and 0.3 metres high) with a discharge capacity of about 6.7 cubic metres per second before dam overtopping. The outlet system was not modified.

The dam was regarded only as an emergency supply for most of the post-World War II period, with a water wagon kept in reserve at Dalveen when the dam ran dry. It is recorded that the dam ran dry in 1920 and wagons of water had to be provided at Dalveen.[19]

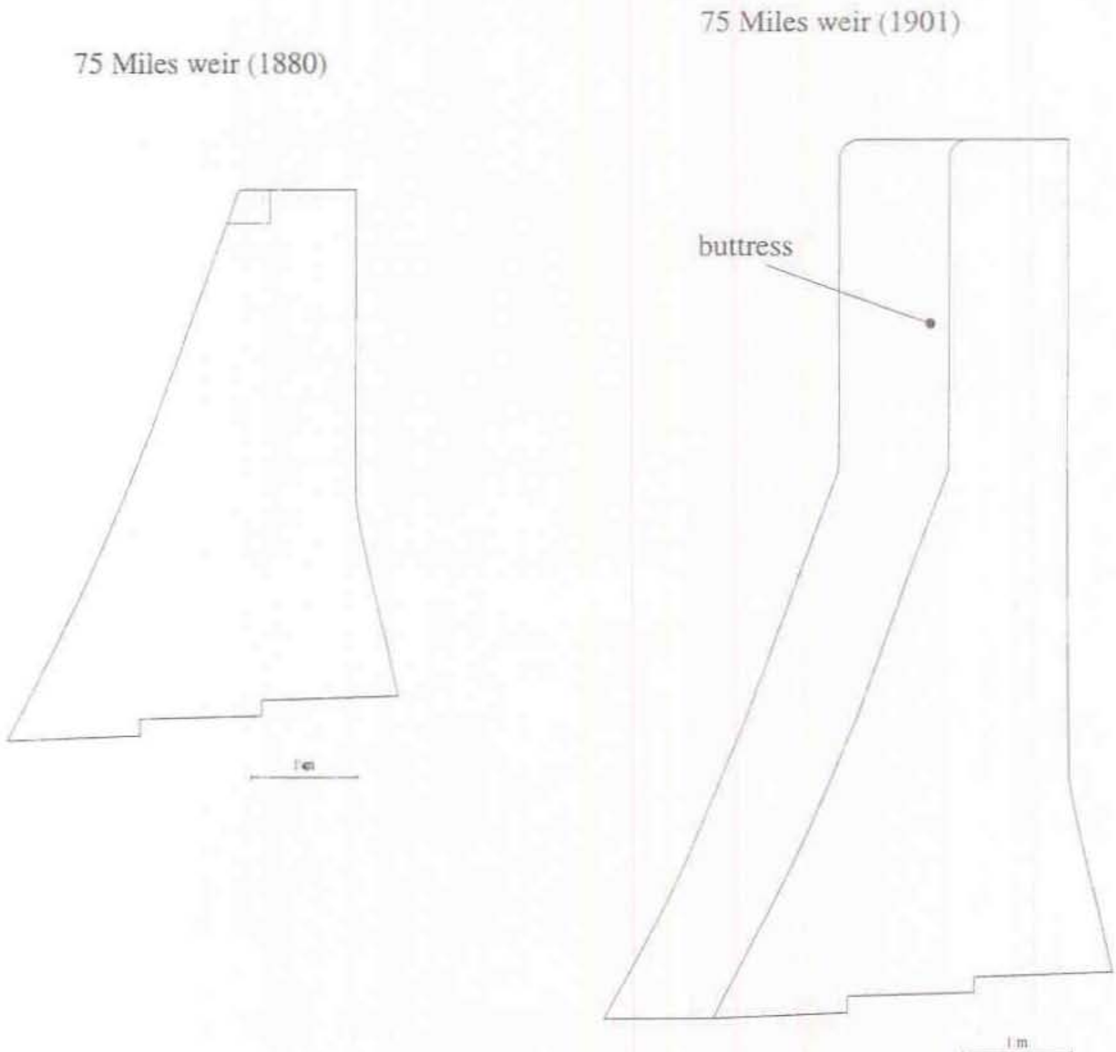
Significance of the Dam

The 75-Mile Dam was the first concrete arch dam built in Australia, and possibly the oldest concrete arch dam in the world. It was the second arch dam completed in Australia after the Parramatta masonry dam (1856). It was also Australia's second dam built entirely of concrete (see below).

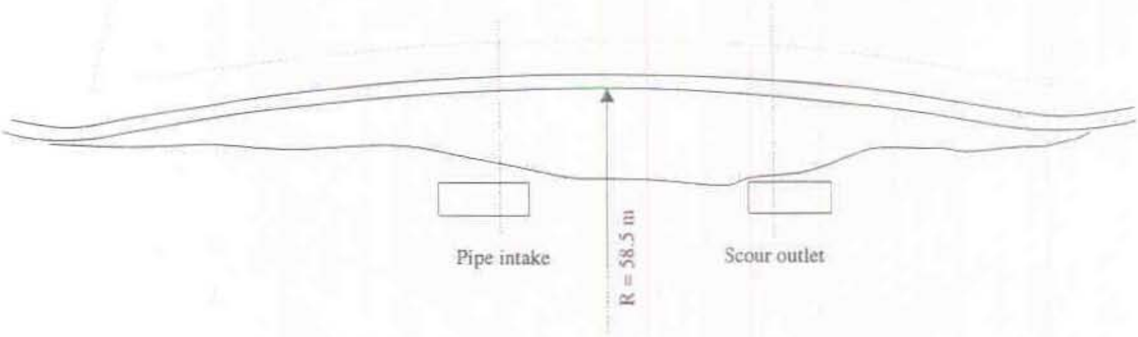
Stanley had contacts with the New South Wales Public Works Department. In 1878, he had 'been placed in communication with the Railway Department, New South Wales, with the object of considering the best mode of ultimately connecting the railway system in this colony [i.e. Queensland] with that of New South Wales'.[20] Stanley himself acknowledged his visit to Sydney where he might have met E. O. Moriarty (1824-1896) and Cecil West Darley (1842-1928).[21]

The 1880 dam is a precursor of the concrete dams built in Australia and in Queensland at later dates (e.g. Lake Manchester dam completed in 1916), and it is one of the earliest concrete dams in the world. The world's first concrete dams were the Boyds Corner dam (New York, USA) built between 1866 and 1872,[22] the Perolles Dam (Switzerland) built from 1869 to 1872,[23] and the Lower Stony Creek Dam (Geelong Victoria, 1873) designed by George Gordon (1828-1907).[24] All these structures were gravity dams.

The Australian expertise in concrete dam design did not originate from United Kingdom. Earth dams were common designs there during the 19th century[25] and the first mass concrete dam exceeding 15-m in height was the Abbeysread dam completed in 1881.[26] In India, the first large concrete structure was the Periar (or Periyar) Dam built between 1888 and 1897, a 47 metre high gravity dam. In Hong Kong, the Tytam dam was completed in 1887. The concrete gravity dam had masonry stone facing. The Sand



Cross-sections of the 1880 and 1901 dams



Elevation view of the 1880 dam

River dam, completed in 1906, was the first concrete dam in South Africa.[27]

It is believed that the concrete construction at 75-Miles was selected because the Gorge tunnel and several culverts were also made in concrete. The tunnel was rendered with concrete. Some concrete preparation took place at the Southern end of the tunnel.[28]

The use of concrete as a construction material for an arch dam marked a turn in the historical development of arch dams because it allowed the development of more advanced arch designs. For example, the double-curvature 'cupola' arch[29] and constant-angle variable-radius arch[30] designs which are common arch dam techniques today: for example, the Moogerah dam (1961, south of Ipswich). Hence he 75-Miles dam is a true milestone in arch dam development.

Use of the Dam

The Warwick-Stanthorpe section became part of the first railway connection from Brisbane to Sydney via Wallangarra, opened on 16 January 1888.[31] The 75-Miles dam was a water supply for the Brisbane-Sydney expresses up to 1930, when the railway link between Brisbane and Sydney was redirected through Casino NSW.

Two events might have triggered the dam heightening: the prolonged drought of 1901 and the introduction of the new B 15 locomotives around 1900, with 8.2 cubic metre tenders. The writer noted with surprise the high location of the dam associated with the very small catchment (one square kilometre) and it is likely that the original reservoir could not store enough water throughout the year. Indeed records indicated that the reservoir was dry several times including prior to 1900, in 1920 when trucks had to bring water to Dalveen to enable trains to proceed and in 1994. The reservoir is little silted today. There was less than 1.5-m of silt on the bottom at the wall in 1994.

During the construction, cement was possibly delivered by railway. The railway track to the tunnel was laid in 1880 and the contractors J. & A. Overend[32] had acquired an American Baldwin locomotive for use on the line.[33]

Current Conditions

The author inspected the dam on 23 January 1998. The dam is in a gully east of the line. The reservoir sits high in the range above the railway. Downstream of the dam, a large concrete culvert[35] (1.8 metres high by 2.5 metres wide) allows water to flow underneath the embankment. Downstream of the culvert outlet, there is a dry rock wall. It is believed that it was built to prevent scour downstream of the culvert.

The dam concrete wall sits on a rock foundation and it was in good condition. The concrete overlays were clearly visible on the buttresses. No seepage was visible through or under the dam, nor at the connection between the first dam crest and the additional section.

View of the dam from downstream on 23 January 1998. Note the 1880 cast iron plate on the central buttress.

View of dam from the left bank on 23 January 1998 with Mr Robertson walking on the spillway crest

The scour outlet valve could be opened mechanically but no water flowed. The pipe outlet valve was operating. The small brick structure, supporting the pipe bend to turn into the water tank direction, was clearly visible. There were two pipe valves: one upstream of the bend and one downstream of the bend. At the time of the visit, the reservoir was full. At the dam wall, a 4 metre long stick could not reach the bottom of the reservoir.

The dam area was managed at the time by Queensland Railways.

Conclusion

The first Australian arch dam was built at Parramatta near Sydney and completed in 1856. Australian engineers pioneered the use of concrete as a construction material during the middle of the 19th century. They were among the first to design concrete dams and especially concrete arch dams. The world's oldest concrete arch dam, the 75-Mile Dam near Warwick, Queensland, was designed by Henry C. Stanley and it was a thick arch design completed in 1880. The 75-Mile structure was made of non-reinforced concrete and it was the first application in the world to an arch dam. The 75-Mile Dam is a true milestone in arch dam development.

The Parramatta and 75-Miles dams are still standing and they demonstrate the soundness of the Australian concrete arch dam design. Further the excellent record of 75-Mile Dam illustrates Queensland engineering expertise in the late 19th century. The writer hopes that the Engineering Heritage significance of the 75-Mile Dam will be soon recognised.

Technical Details

Completed: 1879-1800 (CR 1880); enlarged 1900-01 (CR 1900-01).

River: Mineral Creek catchment, on right hill slope.

Town: south of Warwick, next to Oaklands property. Railway workers camped at Oaklands during construction. The hotel was brought by bullock-wagon.

Capacity: 1.295 or 1.818 cubic metres initially (Plan).

Catchment area: 1 square kilometre

Designer: H.C. Stanley, Chief Engineer (initial and enlargement)

Institution: Queensland Railways

Dam Height: 5.04 metres initially (Plan); 8 to 10 metres as enlarged.

Crest Length: 24.5 metres (Plan); as enlarged, 30 metres (Writer's site inspection)

Construction Material: Concrete (non-reinforced).

Design: Thick arch dam, single radius. As enlarged, curved dam with three concrete buttresses (1.1 x 2.1 square metres) added downstream.

Crest thickness: 1.07 metres (Plan); as enlarged 0.89 metres (Site Inspection)

Base thickness: 2.78 metres (Original Plan; assumed unchanged since).

Radius of Curvature: 58.5 metres (Plan)

Angle of Opening (Central Angle) 24 degrees (Plan)

Gravity section: None

Spillway type: Overflow.

Spillway Capacity: Unknown initially; as enlarged 6.7 cubic metres per second before dam overtopping..

Spillway Dimensions: 24.5 metres wide, crest length; as enlarged 0.3 metres high, 24 metres wide.

Outlet systems: 2, Scour outlet (12 inch diameter) and Pipe intake (3 inch diameter). (Plan)

History of Construction: Construction as part of Warwick-Stanthorpe section of Southern Railway

History of Use: Use for steam engines up to 1969. Part of principal Brisbane- Sydney line 1888-1930.

Present Owner: Queensland Rail. Responsible Manager, Infrastructure Engineer of the Freight Group.

View of dam in January 1998 from the left bank, highlighting the dam wall curvature

Present Use: emergency use since 1950.

Siltation Record: Little

Other: First concrete arch dam in Australia.

Endnotes

The author thanks all the people who provided information and assistance, in particular Ms Chou Y.H., Brisbane, Professor C. O'Connor, Brisbane, Mr Michael Robertson, Warwick, Mr P. Brixie, Warwick and Queensland Railways – Historical Centre, Ipswich and Mr J.D. Kerr, Editor.

1. F.L. Kinstler, 'Dams in Early Australia', *Proc. 9th Nat. Conf. on Engineering Heritage, I E Aust., Ballarat Vic, Australia*, 15-18 March 1998, pp. 75-86.
2. The oldest Australian large dam. Refer Australian National Committee on Large Dams (1970) *Register of Large Dams in Australia*. Australian Nat. Com., Canberra, Australia, 4th edition;. International Commission on Large Dams (1984). *World Register of Dams – Registre Mondial des barrages -ICOLD*. ICOLD, Paris, France, 753 pages.
3. For example, Gouffre d'Enler (Ft. 1866), Ternay (Ft. 1867), La Rive (Ft. 1870), and Paas-du-Riot (Ft. 1873) dams. La Rive dam is also called Le Ban dam. Sankey stated: 'The authority of French engineers [on the subject], who have more thoroughly than any other solved all the attendant difficulties, may safely be followed. The most recent and satisfactory information on this subject is to be round in the Memoires of M. Graeff and M. Delocre [(1828-1908)]' (see R.E. Sankey, *Report on the Coliban and Geelong Water Schemes of Water Supply.* presented to both Houses of Parliament, Victoria (Australia), 11 November 1871 p.20. He referred to Delocre (1866).
   W. Humber, *Comprehensive Treatise on the Water Supply of Cities and Towns with Numerous Specifications of Existing Waterworks*. Crosby Lockwood, London, 1876 p. 123, stated: 'The theory of masonry dams forms the subject of a very interesting and rather elaborate memoir by Delocre of the Administration des Ponts et Chaussses'.
4. See review by H. Chanson and D.P. James, *Historical Development of Arch Dams in Australia: from Advanced Designs to Engineering Failures.* Research Report CE 157, Dept. of Civil Engineering, The University of Queensland, Brisbane, Australia, August 1998 (ISBN 1 86499 0791).
5. Steam locomotives operated in Australia up to the 1970s, with steam engines in use up to 1976 at Ingham, North Queensland.
6. *Brisbane Courier* 21 August 1973 p. 2; Annual Report of the Commissioner for Railways (hereafter CR) 1875 pp. 24-25, 1876 p. 12, 1877 p. 30.
7. J.D. Kerr, 'Centenary of the Southern Line', *Australian Railway Historical Society Bulletin* No. 398, Dec. 1970. p. 265.
8. *CR* 1878 p. 39.
9. *CR* 1879 p. 81, 1880 pp. 92-3, 1881 p. 180.
10. See cast iron plate originally placed on the 'downstream wall face, later placed on the central buttress (after dam heightening).
11. Plan of dam and specifications of design: Stanthorpe Extension, Dam at 74 M 77 chs, Henry' Stanley, 27.3.79.
12. The contractors were J. & A. Overend.
13. The writer re-analysed the stability of the structure and showed conclusively that the dam would be unstable in absence of the abutment reaction force (Chanson and James op.cit.).

14. Plan of dam and specifications of design :Stanthorpe Extension, Dam at 74 M 77 chs, Henry Stanley, 27.3.79.
15. *CR* 1880, p. 80.
16. The water tank was located at 74 miles 37 chains, 0.5 miles downstream of the dam, at a place of horizontal level, because the railway grade (i.e. 1 in 60) was too steep for the trains to stop near the reservoir. The tank stand was erected in 1881. (Distance post-1915 from Toowoomba via Drayton). (CR 1881, p. 108). The water tank was unusually small in itself but water could be easily provided by the 75-Miles dam reservoir.
17. CR 1900-1901.
18. Assumption by the writer based on original plans, site inspection and costs of dam enlargement.
19. Working Timetable, Southern and Western Lines November 1950; *Warwick Daily News* 20 July 1920 p.2 which recorded that the formerly empty dam had overflowed.
20. *CR* 1878.
21. Moriarty was one of the designers of the Parramatta dam (1856). Darley worked with Moriarty and later he supervised the heightening of the Parramatta dam (1898). He designed several concrete thin arch dams e.g., Lithgow No.1 (1896), Moore Creek (1898), Queen Charlotte Vale (1898).
22. A major refurbishment took place in 1990, with the construction of a new spillway (6.1-m wide flip bucket in the central dam section) and the use of post-tensioned anchors to increase the dam stability.
23. Also called La Maigrauge Dam and heightened in 1909.
24. Also called Geelong dam (E. Wegmann, *The Design and Construction of Dams*. John Wiley & Sons, New York, USA, 1922, 7th edition) or Stony Creek dam (B.S.C. Harper, 'Edward Dobson and the Mass Concrete on Stony Creek for the Geelong Water Supply.' *Proc. 9th Nat. Conf. on Engineering Heritage, I E Aust., Ballarat Vic., Australia*, 15-18 March 1998, pp. 97-106.)
25. G. M. Binnie, *Early Victorian Water Engineers*. Thomas Telford, London, 1981 310 pages.
26. G.M. Binnie, 'Masonry and Concrete Dams 1880-1941.' *Industrial Archaeology Review*, X, 1, (1987) pp. 41-58.
27. Schuyler, J.D. (1909). *Reservoirs for Irrigation, Water-Power and Domestic Water Supply*. John Wiley, & Sons, 2nd edition, New York, USA.
28. Traces of sand lot concrete found by Mr M. Robertson.
29. The world's first cupola arch dam was the Ithaca dam (1903, New York, USA) which was designed by Professor G.S. Williams (1866-1931). The structure was designed to be a 27-m high structure but construction was stopped when the dam height reached 9-m because of local opposition.
30. The world's first constant-angle arch dams were built in 1913-1914 and designed by Lars R. Jorgensen (1876-1938): Manila (Philippines) and Salmon Creek (Alaska).
31. R. S. Lee, *The Greatest Public Work. The New South Wales Railways, 1848 to 1889.* Hale and Iremonger, Sydney, Australia, 1988, 184 pages.
32. Overend built also the dam.
33. J. Armstrong, *Locos in the Tropics*, Vol. 1, Australian Railway Historical Society, 1985, p. 98, footnote 2.
34. Probably built between 1878 and 1879.