Nomination

of

DARTMOUTH DAM

as a

NATIONAL ENGINEERING LANDMARK

Dartmouth Dam and Spillway

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Engineering Heritage Australia (Victoria)
Engineers Australia

June 2004

CONTENTS

INTRODUCTION

The River Murray is 2500km long, rising in the Australian Alps and discharging into the sea in South Australia. There are very large irrigation areas along its length which are dependent on the river for their survival and prosperity. The river also supplies many inland towns along the river. In South Australia pipelines carry its water to Adelaide, the Iron Triangle and many country towns.

Beginning in 1915 the River Murray Commission has overseen many developments. Thirteen locks and weirs were constructed to provide ponds for irrigation pumps and improved navigability for river traffic. The first major storage was Hume Dam completed in 1936. Its reservoir capacity was 1.5 million megalitres. In 1961 the installation of gates on the spillway crest and some other measures increased the storage to 3.0 million megalitres. The demand for greater reliability in times of drought led to the need for more storage which was provided by Dartmouth Dam in 1979. Its reservoir capacity is 4.0 million megalitres.

Dartmouth Dam is located on the Mitta Mitta River in north-eastern Victoria, about 80km south-east from Wodonga. See location map. Water released from the reservoir flows down the river into Lake Hume. Built for the then River Murray Commission, the constructing authority was the State Rivers & Water Supply Commission of Victoria, the designer was the Snowy Mountains Engineering Corporation and the main contractor was Thiess Bros Pty.

The dam itself is an earth core rockfill structure 180m high, the highest dam in Australia. It is a prime example of a relatively new dam type, developed after World War 2 and particularly economical where a high embankment is required. Its construction was state-of-the-art at the time.

Dartmouth Dam was not chosen as one of the 25 dams nominated for listing on the Register of the National Estate in 1999, mainly because the Heritage Dams project team did not receive a sufficiently compelling proposal.

In 2001 the Engineering Works of the River Murray were recognised by Engineers Australia as a National Engineering Landmark. Dartmouth Dam is a significant component of those works but the dam itself has not been plaqued.

Dartmouth Dam is owned by the Murray Darling Basin Commission and operated by Goulburn-Murray Water for River Murray Water.

PLAQUE NOMINATION FORM

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

Name of work: **DARTMOUTH DAM**

The above-mentioned work is nominated to be awarded an

National Engineering Landmark

Location, including address and map grid reference if a fixed work:

On the Mitta Mitta River, about 70km south-east of Wodonga.

Aust Map Grid Zone 55, 545E, 5954N.

Owner (name & address): **Murray Darling Basin Commission**

GPO Box 409, Canberra ACT 2601

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

Access to site: **From Wodonga and Tallangatta via Omeo Highway to Mitta Mitta, then 20km by dam access road**.

Nominating Body: **Engineering Heritage Australia (Victoria)**

....
Chair of Nominating Body

Date: ....

....
Chair of Division Engineering Heritage Group

Date: ....

Figure 1 Location Map

HISTORY

Since the 1860s the three colonies New South Wales, Victoria and South Australia were unable to agree on the development of the River Murray. South Australia was very keen to improve navigability for river traffic which took supplies into and produce out of the vast inland region via South Australia. All States were keen to expand irrigation areas using the water. However improved reliability in the flow was needed to combat the devastating effects of severe droughts which, in Australia, occurred all too often.

After Federation, the new Commonwealth Government brought the States together and eventually brokered an historic agreement in 1914 to establish the River Murray Commission, financially supported by all four governments. Under the agreement the storage in Lake Victoria (near south Australia) was to be raised, and 26 weirs and locks were to be built between Blanchetown in South Australia and Echuca in Victoria to make the river passable by shallow-draft vessels all year round. The weirs would create useful ponds from which water could be pumped or diverted to adjacent irrigation areas. As the NSW and Victorian railways had long since captured most of the trade, only 13 locks and weirs were built, in the period 1922 to 1937, so that only the lower part of the river was fully locked. Instead five barrages were built across the five channels at the Murray mouth, to exclude salt water from the lower reaches of the river.

The major task for the River Murray Commission was to construct the Hume Dam near Albury, to catch the winter flows and release them in the irrigation season. This was a very large project undertaken between 1920 and 1936. New South Wales constructed the concrete gravity spillway across the river bed, and Victoria was responsible for the 1.3km long embankment on the left bank. The capacity of Lake Hume was 1.5 million megalitres (compared with the annual average flow of about 4 million megalitres). By 1939 Yarrawonga Weir had been built 230 river kilometres below Hume Dam, to divert some of the river flow into two major canals feeding irrigation areas both north and south of the river.

Hume Dam was designed to be raised and, by 1961, 29 large steel gates had been added to the spillway, thereby doubling the reservoir capacity. The town of Tallangatta was moved out of the storage area and rebuilt at a higher level.

South Australia, being far downstream and getting last use of the water, was particularly keen to maintain the river flow in dry periods and proposed the construction of Chowilla Dam just within the State border. This 6.25 million megalitre storage would have given South Australia more control over its share of the water. The dam was to be an earth embankment 5.6km long, spanning the River Murray and two creeks, and founded on a great depth of sand. However, concerns about the cost, losses by evaporation and rising salinity levels led to the abandonment of the site in 1967 (and the loss by the SA government of the subsequent election).

The Mitta Mitta River is a major tributary which flows into Lake Hume on the Victorian side. A suitable damsite was found about 110 river kilometres upstream, at the Dart River junction (hence Dartmouth). In order to store 4 million megalitres, the dam had to be 180m high, higher than any existing dam in Australia. The River Murray Commission appointed the State Rivers & Water Supply Commission of Victoria to be the constructing authority, the Snowy Mountains Engineering Corporation was retained to design the dam and Thiess Bros won the contract to build it.

Construction of the site access road began in 1972, followed by the village to accommodate 200 families. Dam works started in 1973 with the excavation of the river diversion tunnel. The major contract for the embankment was let in 1974, and the dam was completed in 1979, at a cost of $179 million. A drought in 1982-83 called on its water to be released for irrigation in 1983. The reservoir filled for the first time in 1989.

A 150MW power station was constructed at the toe of the dam to generate power from the irrigation releases. A second dam below the station has created a regulating pond which absorbs fluctuating discharges based on power demand and releases more even flows to the river downstream.

EARTH CORE ROCKFILL DAMS

Earth core rockfill dams (ECRDs) consist of a central earth core as the impervious element, supported both upstream and downstream by compacted rockfill shoulders. See Figure 2. Between the earth core and the downstream rockfill there are narrow zones of fine material to prevent any earth particles from being washed into the voids of the rockfill should a leak develop. Similar zones on the upstream side prevent erosion of the core material when the reservoir level changes. Because the rockfill is strong and free-draining, the outer slopes can be quite steep, thus minimising the volume of material in the embankment and the cost of the dam.

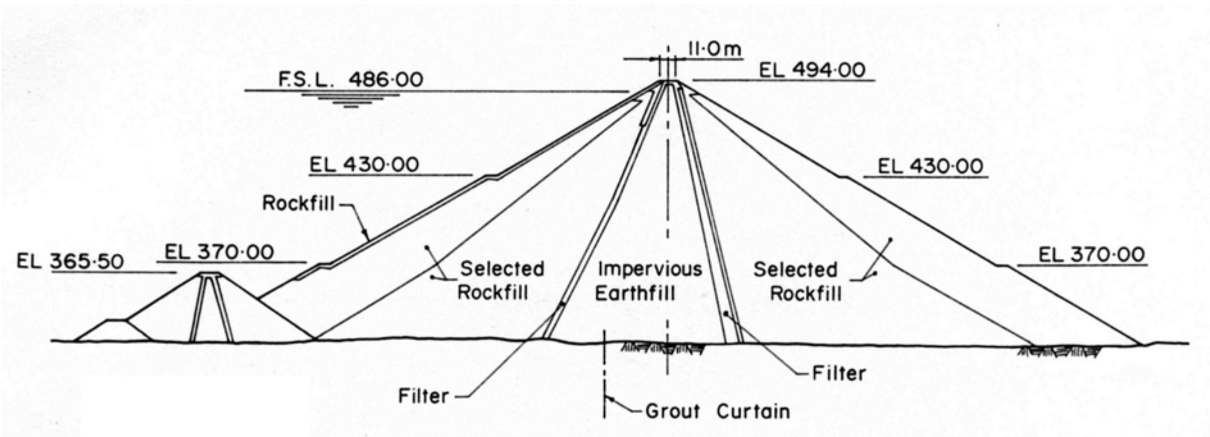

Figure 2 Dartmouth Dam Cross section

The first ECRD in Australia was the 20m high Bradys Dam in Tasmania completed in 1953. There the rockfill was dumped and not compacted. Dams up to 55m high were built with dumped rockfill. The use of compacted rockfill began about 1965 and became universally adopted. Compaction greatly reduced the amount of settlement which occurred as the embankment was built, and the stable outer slopes could be steeper than for dumped rockfill. Typically well-graded rockfill was placed in layers 1 to 2 metres thick and compacted with a 10 tonne vibrating roller.

The crown for the highest ECRD in Australia passed rapidly from Geehi (91m, 1966), Blowering (112m, 1968) and Talbingo dams (162m, 1971), all in the Snowy mountains Scheme, to Dartmouth Dam (180m, 1979) in Victoria. See Figure 3. The three highest dams in Australia are all earth core rockfill dams. It has proved to be the most economical type where a very high embankment is needed. In its development phase, several dam building authorities in Australia contributed their expertise to its refinement. In particular, designers within the Snowy Mountains Engineering Corporation had previous experience with this type of dam, having designed Geehi, Blowering and Talbingo dams when working in the Snowy Mountains Hydro-electric Authority.

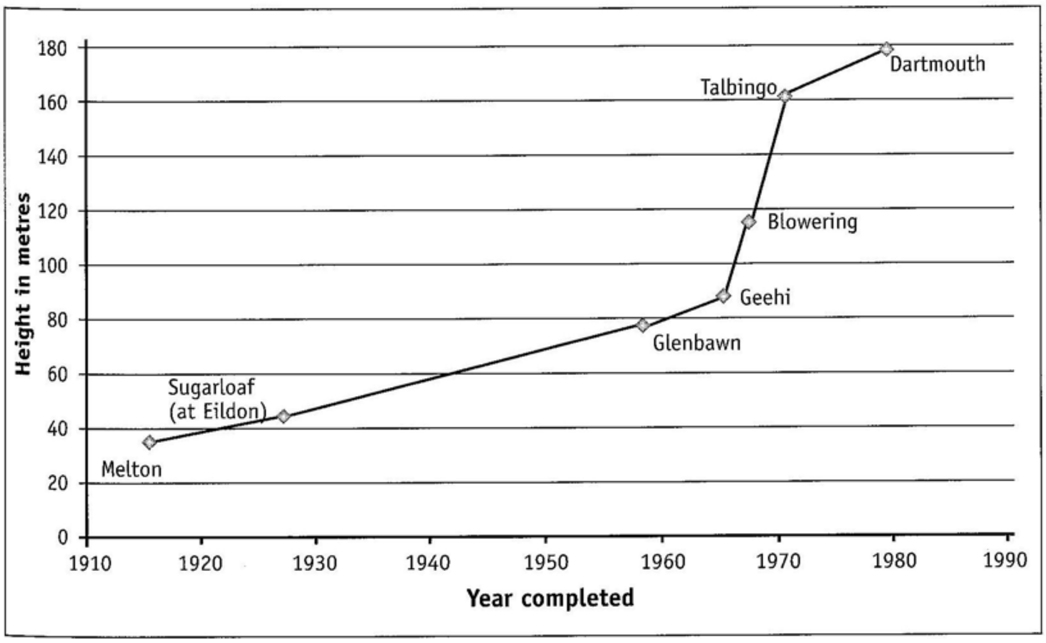

Figure 3 Highest earth core rockfill dams when completed
(Reference 9)

PHYSICAL DESCRIPTION OF DAM

Dartmouth Dam consists of the dam itself, a river diversion tunnel and cofferdam, a spillway, high-level and low-level outlets and a hydro-electric power station.

The dam is 180m high, 670m long and contains 14 million cubic metres of material. The catchment area is 3,600 sq km, the surface area at full supply level is 63 sq km, and the spillway crest length is 91m.

Figure 4 Dartmouth Dam from left abutment (quarry side)

Several features are noteworthy:

- The height of a dam is a very significant dimension, as it represents the maximum hydraulic pressure which the watertightness of the embankment and the foundation must resist. A dam of twice the height contains 6 to 8 times the volume of material. Thus the 180m high Dartmouth Dam was a major project requiring very careful design and construction.
- A 15m high cofferdam was designed to divert summer flows through the 6m diameter diversion tunnel while the main embankment was being constructed. However delays to the schedule resulted in the need to divert winter flows as well. Consequently the contractor built a 50m high cofferdam at short notice in 3½ months. The rockfill on its downstream face was protected with steel mesh to prevent it washing away if it were overtopped by floods. A cofferdam of this height is most unusual, but its construction avoided potential delays of 5 and 8 months in impoundment and completion respectively. (Reference 4)
- The rockfill quarry on the left bank was designed not only to supply the vast quantity of rock for the embankment, but also to dissipate the energy of the water flowing over the spillway, on its way down to river level. The quarry was developed in a series of benches (steps) about 15m high which acts as a cascade of waterfalls during flood discharges. As a result, the concrete spillway consists of a crest and a relatively short chute which delivers the flow to the top bench of the quarry. The alternative of a concrete chute all the way down from the crest to river level would have been much more expensive, and a substantial energy dissipator would have been required to calm the very high velocity water where it entered the river.

Figure 5 Dartmouth Dam during spilling down the quarry benches

- As construction of the embankment proceeded, it was important that the earth core was free to settle under its own weight, in order to maintain its watertightness. Readings from embedded instruments showed that the filter zones on both sides of the core were settling less than the core and thereby partly resisting core settlement. To counter this undesirable effect, compaction of the filter zones was progressively reduced until similar rates of settlement were measured. (Reference 6)
- The dam incorporates two outlets for the release of irrigation water. The high-level outlet draws water from the upper 30m of the reservoir, and delivers it via a tunnel under the left abutment to either the outlet valve or the power station. See figure 6.

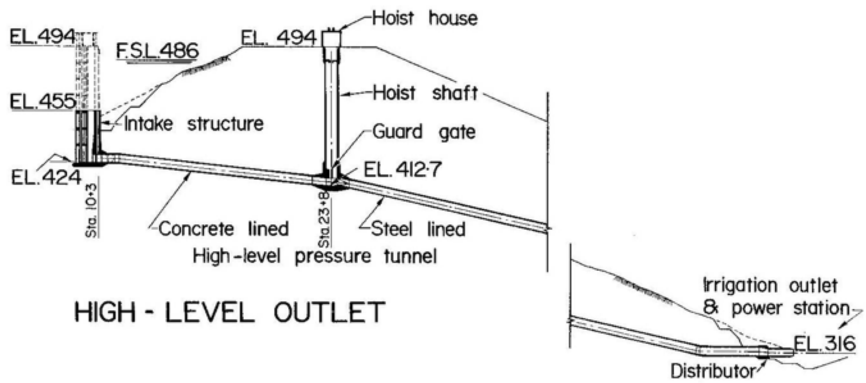

Figure 6 Dartmouth Dam High Level Outlet

- A serious incident occurred at the power station about 1991. At a time when the reservoir level was very high, a hydraulic surge up the hoist shaft dislodged a steel beam which dropped down the shaft and was carried along the tunnel to the power station. There the beam forced the guide vanes in the spiral casing to shut instantaneously and the immediate water pressure rise was sufficient to cause severe structural and mechanical damage. A substantial part of the station and its machinery had to be demolished and rebuilt. In order to determine responsibility, there was a prolonged legal action involving the State Rivers & Water Supply Commission who controlled the hoist shaft, the State Electricity Commission who owned and operated the power station, and their respective insurance companies.
- The low level outlet, operating under a much higher head, is available for releases when the reservoir is low. See Figure 7. There are twin discharge-regulating gates side by side on this outlet. They are located inside the tunnel and the enormous energy (up to 120MW) of the discharged water is dissipated within an enlarged length of tunnel (the expansion chamber) lined with reinforced concrete.

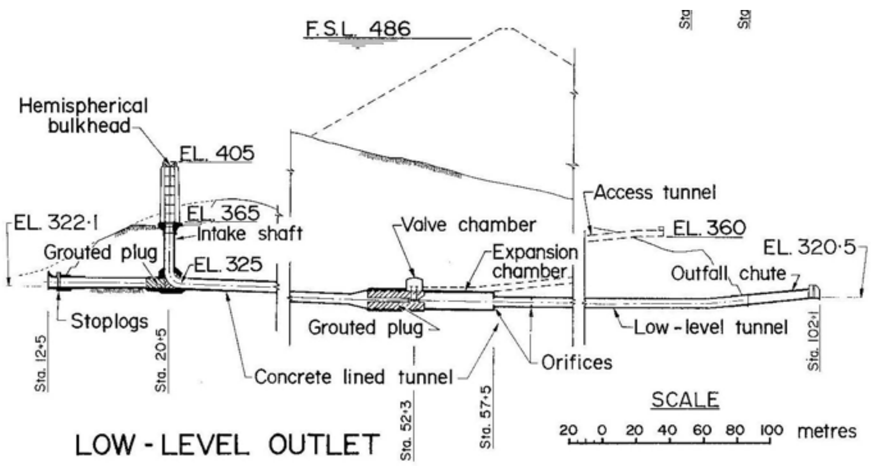

Figure 7 Dartmouth Dam Low Level Outlet

- When the gates were commissioned, severe cavitation implosions occurred and it was concluded that the outlet could not be operated safely. Vibrations was felt at the concrete outlet structure 500m downstream. The problem could be reduced by injecting large quantities of compressed air, or by arranging for the water jets leaving the gates to create a vacuum which would suck the air in. Both methods were tried. Guided by some hydraulic model test results, the outlet was modified, just in time for prolonged releases in 1983 when a severe drought had kept Lake Hume at a low level. Initially the outlet supplemented releases from the high-level outlet but, when the lake level dropped too far, the low-level outlet had to meet the whole demand. After operations ceased, inspections showed that both the stainless steel and concrete surfaces were in good condition, but some stainless steel surfaces had many dents or a sand-blasted appearance. Further tests and modifications were planned to see whether cavitation could be reduced further. Noise levels in the valve chamber (Figure 7) above the gates due to both cavitation crackles and high air velocities were very uncomfortable for the operators. (Reference 7)

Plaquing Nomination Assessment Form

1. BASIC DATA

Item Name:	Dartmouth Dam
Other/Former Names:	None
Location (grid reference if possible):	AMG Zone 55, 545E, 5954N.
Address:	Dartmouth
Suburb/Nearest Town:	Tallangatta
State:	Victoria
Local Govt. Area:	Shire of Towong
Owner:	Murray Darling Basin Commission
Current Use:	Major water storage providing drought protection for irrigation in the Murray River, and water supplies for Adelaide and regional South Australia.
Former Use (if any):	None
Designer:	Snowy Mountains Engineering Corporation
Maker/Builder:	Thiess Bros Pty Ltd
Year Started: 1972	Year Completed: 1979
Physical Description:	An earth core rockfill dam 180m high, 670m long, containing 14 million m^3 of material, with a chute spillway, high and low level outlets and a 150MW power station. Storage volume 4 million megalitres.
Physical Condition:	The dam is currently is good condition, substantially as built and well maintained. Modifications have been made to the low-level outlet to reduce cavitation, and some dental concrete has been placed on the spillway benches where floods flows have caused some erosion. Dam safety practice requires the dam to be inspected regularly, instrument readings to be taken and assessed, and comprehensive safety reviews to be carried out periodically, in accordance with guidelines published by the Australian National Committee on Large Dams.
Modifications and Dates:	No significant alterations
Historical Notes:	See History section on page 6.
Heritage Listings	None

2. ASSESSMENT OF SIGNIFICANCE

Historic Phase

The completion of Dartmouth Dam in 1979 was the latest major project in the long term development of the River Murray which began with the historic agreement in 1915 between the Commonwealth and the three States to establish the River Murray Commission (now the Murray Darling Basin Commission). The dam is a further example of what the four governments can achieve by working together.

Historic Individuals or Association

The construction of the dam is associated with three major Australian organisations:

The **State Rivers & Water Supply Commission** of Victoria (SR&WSC) was the constructing authority. Established in 1905 to control water supplies outside Melbourne, the SR&WSC developed into one of the leading dam building authorities in Australia. Between 1920 and 1984, it was responsible for the design and construction of 30 large dams for town water supplies and irrigation throughout Victoria.

The **Snowy Mountains Engineering Corporation** (SMEC) was responsible for the dam design. This team had previously worked in the Snowy Mountains Hydro-electric Authority which built the world-famous Snowy Mountains Scheme between 1949 and 1972. That scheme involved 16 large dams. Since 1972 SMEC has carried out many major projects both in Australia and overseas.

The contractor for the dam was **Thiess Bros Pty Ltd**. This Queensland firm won several major dam and tunnel contracts on the Snowy Mountains Scheme in competition with international contractors, demonstrating that Australian firms could operate successfully in the big league.

Creative or Technical Achievement

Dartmouth Dam is higher than any other dam of this type in Australia, and is the highest dam in Australia. It was state-of-the art when constructed, and has proved reliable in 25 years of operation.

The dual use of the quarry as a rockfill source and a spillway dissipator is innovative and economical. There may be other examples but not many.

In order to avoid delaying embankment construction in the river bed until the next summer, the contractor constructed a 50m high cofferdam in a very short time, to enable winter flows to pass through the diversion tunnel.

Modifications to the low level outlet reduced cavitation to a level where prolonged releases could be made safely to mitigate the effects of the 1982-83 drought.

Research Potential

The low-level outlet is an example of a high-head outlet which is not cavitation free. There is an opportunity to carry out full-scale experiments with the objective of reducing cavitation in this and other existing high-head outlets.

The devastating incident which damaged the power station highlighted the importance of the two operating authorities working together. An examination of this well-documented example would disclose why this did not occur at Dartmouth.

Social

Water from the River Murray is used to irrigate 730,000 hectares of land supporting livestock, crops and fruit growing. The river itself offers recreation and tourism.

The construction of Dartmouth Dam met the pressing need for a long-term reserve storage for the River Murray system. The water in Lake Dartmouth is highly valued by a very large population spread right along the River Murray, in Adelaide and over a substantial area of non-metropolitan South Australia. The water is used to reduce the impact of periodical droughts. Completed in 1979, its value was proved in 1983 when its partially-filled reservoir met irrigation requirements during a drought when Lake Hume was unable to do so. The value of the water will increase as the need for environmental flows is added to the existing allocations for irrigation and town supplies.

Rarity

The type of dam is not rare, but there are only three dams in Australia over 150m high, namely Talbingo 162m, Thomson 166m and Dartmouth 180m.

Representativeness

Dartmouth Dam is a prime example of a modern earth core rockfill dam. It has all the typical features – a central earth core, filter zones, compacted rockfill shoulders, meticulous foundation treatment and so on. It is fully instrumented so that its behaviour in service can be carefully monitored.

Integrity/Intactness

The dam remains virtually in as-built condition and has not suffered any significant deterioration in its 25 year life to date.

STATEMENT OF SIGNIFICANCE

Dartmouth Dam is important for its key role in the River Murray system, for its association with three leading dam building organisations, for its record height and as the prime example of a relatively new type of dam.

In flowing 2500km to the sea the River Murray supports a vast inland population in three states through irrigation and town water supplies. Adelaide is heavily dependent on Murray Water and pipelines carry supplies to other parts of South Australia. The reliability of flows is vital for the livelihoods and prosperity of a great many enterprises.

Dartmouth Dam is the largest water storage in the River Murray system. While Lake Hume is able to catch the winter flows for release during the irrigation season, Dartmouth's role is to supply water during periodic droughts when Lake Hume is depleted. This occurred in 1983, only four years after its completion.

Assessed Significance National State Local (*circle the relevant item*)

National Engineering Landmarks were awarded to Cethana Dam and Gordon Dam in Tasmania in 2001. It is proposed that the Dartmouth Dam award be made simultaneously with the NEL for Hume Dam in 2005.

DRAFT CITATION

DARTMOUTH DAM

This central core rockfill dam is180m high, the highest dam in Australia. The Snowy Mountains Engineering Corporation designed the dam and Thiess Bros built it under contract to the State Rivers & Water Supply Commission of Victoria. The dam retains the largest storage (4 million megalitres) in the River Murray catchment. Its water is reserved for use when Lake Hume is depleted by drought. Irrigators, cities and towns in three States rely on this storage in tough times. (78 words)

The Institution of Engineers Australia
Murray-Darling Basin Commission, 2005

APPENDIX A

MDBC Reference No: MDBC: FA 0454

Your reference:

River
Murray
Water
A Business Unit of MDBC

5 February 2002

Mr Michael Clarke
Chair, Engineering Heritage Australia
26A Campbell Avenue
Normanhurst NSW 2076

Dear Michael,

Subject: Historic Engineering Plaquing of Hume and Dartmouth Dams

Thank you for your letter of 24 January 2002 seeking the Commission's concurrence to plaquing Hume and Dartmouth Dams as National Engineering Landmarks.

Further to the discussion last week between you and David Dreverman, I am pleased to confirm the Commission's support for this initiative by the Institution of Engineers, Australia. In doing so I wish to clarify that:

- The award of National Engineering Landmark will in no way impact on our making future changes to these working assets
- The nomination submissions will be prepared by the Institution of Engineers, Australia
- A separate ceremony will not be held at Hume Dam. Rather the information plaque will be unveiled as part of an opening of remedial works or some other suitable occasion
- The information plaque at Hume Dam will be placed adjacent to the National Engineering Landmark marker and information plaque for the River Murray Works, which were awarded last October. Accordingly a second marker will not be required.

In relation to Hume Dam contact should be through David Dreverman, who will liaise with both State Water and Goulburn-Murray Water as necessary.

For Dartmouth Dam, the Victoria Committee should liaise with:

Mr David Jeffery
Murray Headworks Manager
Goulburn-Murray Water
Lake Hume Office
Private Bag 2
Wodonga Victoria 3691

Phone 02 6049 8251
e-mail *djeffery@g-mwater.com.au*

To assist with your submission for Hume Dam I have attached copies of a paper on Hume Dam presented at ANCOLD Conference in 2000 and a recent article prepared for Landcare Magazine.

We look forward to working with you and your colleagues on this initiative and appreciate the recognition of these two major dams by the Institution.

Yours sincerely

David Dole
General Manager

Cc: David Jeffery

APPENDIX B

References

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2. Maver JL & Michels V, "New Dartmouth Dam on Australia's River Murray System", *2nd World Congress on Water Resources*, India, December 1975.
3. Maver JL & Michels V, "Australia's Highest Dam - Dartmouth", *World Dams Today*, 1976.
4. SRWSC, "50m high cofferdam for Dartmouth Dam", ANCOLD Bulletin No 45, October 1976.
5. Maver JL, Michels V & Dickson R S, "Dartmouth Dam Project: Design and construction progress", *Transactions of the Institution of Engineers, Australia* Vol CE20, No 1 1978 (copy attached).
6. Cummins P J, "Instrumentation of Dartmouth Dam – installation and operation experience", ANCOLD Bulletin No 53, April 1979.
7. Dickson R S & Murley K M, "Dartmouth Dam low-level outlet aeration ramps", ANCOLD Bulletin No 66, December 1983.
8. ANCOLD Register of Large Dams in Australia, Australian National Committee on Large Dams, 1990 and updated at www.ancold.org.au.
9. Cole B, *Dam Technology in Australia1850-1999*, Australian National Committee on Large Dams Inc, 2000.
10. Cole B, *Australia's 500 Large Dams – conserving water on a dry continent*, Australian National Committee on Large Dams Inc, 2003.

ATTACHMENT

Technical Paper: Maver JL, Michels V & Dickson R S, "Dartmouth Dam Project: Design and construction progress", *Transactions of the Institution of Engineers, Australia* Vol CE20, No 1 1978.