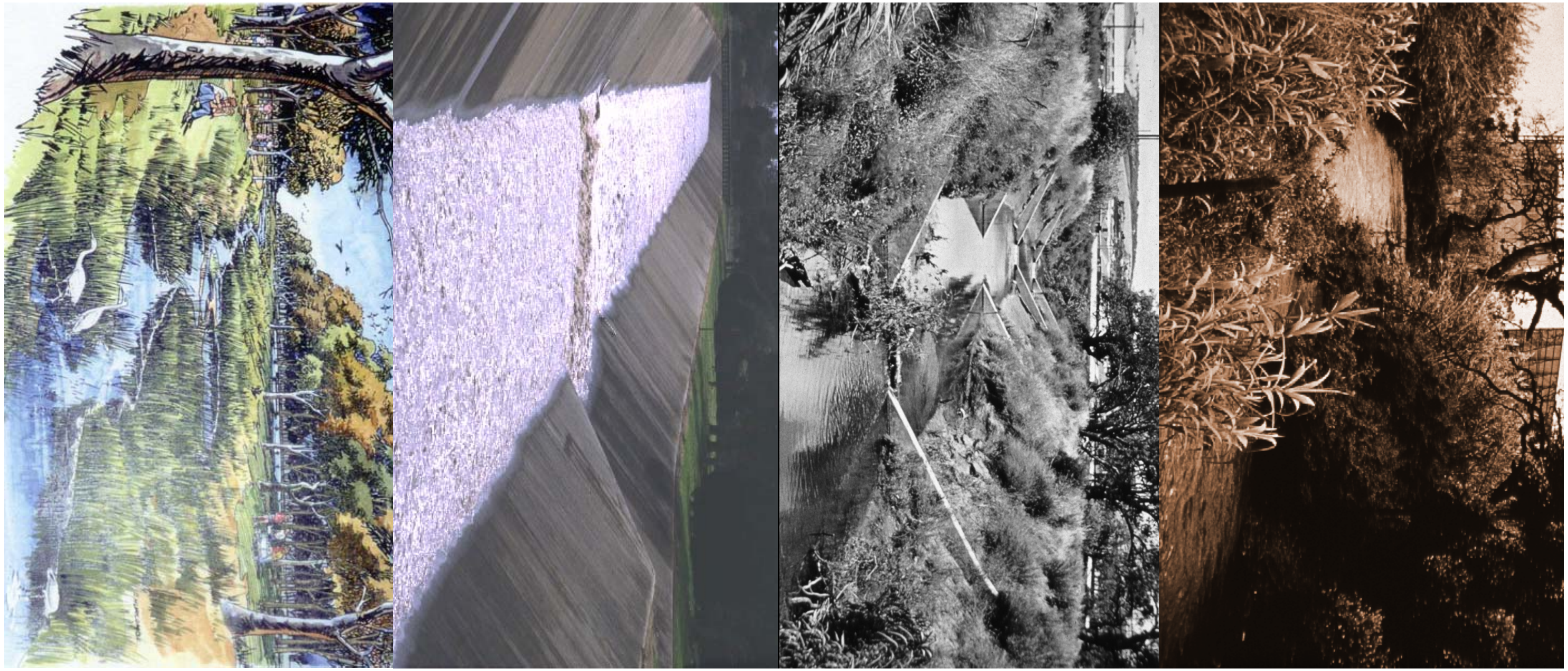

# Water history – Lessons for the future

Proceedings of the conference held at Goolwa, South Australia, 28 September 2001

Organised by the Hydrological Society of South Australia Inc.; Institution of Engineers, Australia, SA Division, Engineering Heritage Branch; and Stormwater Industry Association; with advice from the History Trust of South Australia

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All full papers in the table of contents were reviewed by the technical committee.

Cover photographs: **Sturt River "through the ages":** from top to bottom:

**c 1964**, November
Sturt River at Mitchell Park, near Marion Drive-In theatre north of Sturt Road. Natural channel
Source Arthur Beales, photographer unknown, believed to be teacher at Westminster School.

**c early 1970s**
Sturt River, Mitchell Park, near Marion Road.
Hydraulic drop structures, about three years after construction.
Source as above.

Constructed **mid 1970s**, photo c 1992.
Sturt River, Parkholme, near Oaklands Road. Concrete channel
Photograph Bart van der Wel.

**2000 Artist's impression**
Sturt River, Oaklands Park, south of Oaklands Road, after proposed reclamation from concrete.
Reproduced with assistance and kind permission from Ken Schalk, Tonkin Consulting.

**Acknowledgments**

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**Editors:** Mr Bart van der Wel, Ms Susan Lee



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Institution of Engineers, Australia, SA Division, Engineering Heritage Branch

# Water History –

## lessons for the future

Friday 28 September 2001
PS Murray Queen, Goolwa, Australia

## Contents

**Author and paper** *Page*

# The five "landmarks" of stormwater management in Adelaide

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**Summary**
The paper reviews the four main "landmarks" which can be recognised in the evolution of Adelaide's stormwater control/management system: William Clark's visit in 1877; the 1931 flood; the Drainage Subsidy Scheme (late 1960s); and creation of the Catchment Boards (1995). The "fifth landmark" is the current initiative by Planning SA to introduce stormwater detention/retention practices to Adelaide councils. A hypothetical catchment mathematical model is established to compare the effects of OSD and OSR on downstream flood peaks. The detention tanks are shown to be too small; the retention trenches performs well and represent an attractive option. These outcomes have been recognised during the consultation process, however strong opposition to the latter has been expressed from the building/footings 'lobby'. A case for OSR based on Mitchell's analysis and "emptying time" considerations is offered for "A", "S" and "M-D" soils. The case is extended for consideration with "H-D" and "E-D" (reactive) soils.

## 1. INTRODUCTION: SOME BACKGROUND

The manner in which stormwater has been managed in the past and is likely to be managed in the 21st Century – in keeping with the Seminar theme – represents an evolution with five recognisable steps or "leaps" in understanding or implementation. The **first** of these occurred in 1877 with the visit to South Australia by Mr. William Clark, an eminent British civil engineer, invited to the Australian colonies to advise their governments on important water problems of the day.

His visit to Sydney resulted in the construction of the Bondi sewerage outfall scheme which served that city without change for 100 years and, in modified form, still functions today. His visit to Melbourne bore fruit in the Werribee Sewage Treatment system, expanded but still operating in much the same way Clark advised in the mid-1870s. In Adelaide he recommended a sewage farm at Hindmarsh – transferred to Islington – which served the city at first totally (until 1906) then partly until the 1920s.

But there was one element of seemingly unsolicited advice which Clark bestowed on each of the colonies, borne of bitter experience in the U.K., namely, "manage wastewater and stormwater in **separate** systems: don't put them together!" It is to the credit of our city forefathers that Clark's advice was heeded, saving us, in Australia, from the unfortunate legacy of combined system infrastructures which plague the majority of European and North American cities to this day.

While Adelaide's (separate) stormwater drains did result in flooding of the River Torrens/Sturt River "bottom lands", in the early decades of the 20th Century, the use of this land for (mainly) market gardens did not cause the outcry that it would today. That occurred when 21 $km^2$ of Adelaide's western suburbs were inundated by floodwaters in September 1931.

The political/legislative response to this (**second** "landmark") was a major programme of drainage works (1935 – 1940) which included construction of the River Torrens "breakout channel" in 1940. What might be seen as completion of the programme was the straightening/lining of Sturt River in the late 1960s/early 1970s, to convey storm runoff from over 100 $km^2$ of urban landscape.

The **third** significant "landmark" in Adelaide's stormwater evolution was the Drainage Subsidy Scheme created in the 1967 and administered until recently by the Highways Department or its successors. This scheme, unique in Australia, offered 50% subsidy for approved drainage works for urban catchments greater than 40 ha (originally 100 acres). The approval process required by the scheme ensured that drainage programmes developed by and/or for Councils were integrated into an overall, city-wide plan. In its latter years, the Scheme was responsible for subsidy-funding some of the most innovative stormwater management and environmentally positive projects undertaken in Australia. Among the latter were:

- stream "restoration" programmes carried out in Second, Third and Fourth Creeks, Western Flat creek (Mt. Barker) and North Para River in the 1980s;
- storm drainage works constructed at Golden Grove in the 1980s;
- "source control" stormwater projects carried out at New Brompton Estate, St. Elizabeth Church Warradale, and Parfitt Square (Bowden) in the 1990s.

Legislation enacted in 1995 setting up the Patawalonga and Torrens Water Management Catchment Boards is suggested as the **fourth** "landmark". It is at this point, however, that a significant differentiation has emerged in the way "stormwater management" is interpreted in Adelaide. To the Catchment Boards, the problems posed by stormwater are, largely, those of pollution conveyance/disposal with "solutions" focussed on the technologies of trash racks, GPTs and wetlands to improve water quality discharged to receiving waters. To Councils, the problems of **flood control**, particularly in the wake of urban consolidation, are dominant.

It is this latter concern that has produced the **fifth** "landmark" in the evolutionary process – that of introducing detention/retention technology to combat the threat of "flooding" in the Adelaide urban landscape. However, unlike the previous milestones, all of which were clearly focussed and productive in their outcomes, the fifth "landmark" enters a realm of nation-wide and local technical controversy.

The unwitting pawn in the South Australian theatre of this debate has been Planning SA, which was commissioned to "sort out" the uneven playing field encountered by the building industry in its regulatory dealings with Adelaide councils. The aim of this article is to add some "light" to the controversy, by exploring the consequences for urban flooding in Adelaide of the compromise which has been tabled by Planning SA in its Development Act 1993 Minister's Specification (Planning SA, 2001a) "On-site Detention and Retention of Stormwater" – Draft for Consultation and the associated "Guidelines" document (Planning SA, 2001b).

Before commencing the review, the authors of this article wish to make clear their collective opinion, that Planning SA and its officers have acted in a competent and fully professional manner in their handling of a difficult assignment. They have produced draft documentation which represents the best outcome that could possibly be achieved given the industry representation which was involved in the process.

## 2. LANDMARK No 5 DETENTION/RETENTION PRACTICE IN ADELAIDE

### 2.1 An introductory note

**Detention** is defined as "the holding of runoff for short periods to reduce peak flow rates and later releasing it into the urban drainage system to continue in the hydrological cycle. The volume of surface runoff involved in this process is relatively unchanged."

**Retention** is defined as "the process and schemes whereby stormwater is held for considerable periods causing water to continue in the hydrological cycle via infiltration, percolation, evapotranspiration and not via direct discharge to the urban drainage system." (Planning SA, 2001b)

There is no doubt that **both** technologies, correctly applied as part of the building approval processes undertaken by Councils in their day-to-day dealings with the public – including developers - lead to reductions in "downstream" flooding. The primary question which should be at issue here is: which technology provides the greater benefit for the same investment?

### 2.2 The "flooding" issue: allotment runoff

It is possible, with the aid of the various tables presented in the Minister's Specification, to determine dimensions for detention and retention installations matched to virtually any contributing roof area, including (by extrapolation) factory roofs. The tables have therefore been used to select the following typical case for comparison :

- Allotment area : 400 $m^2$
- Roof area (60% of site area; 75% contributing) : 180 $m^2$
- Storm Duration (Tables) : 25 mins (detention); 30 mins (retention)
- Detention tank volume ("5-years" ARI) : 1455 L; orifice 20 mm $\phi$; max (tank) water depth = 1.2 m;
- Retention trench volume ("5-years" ARI): 7.8 $m^3$ (gravel-filled trench, M-D soil).

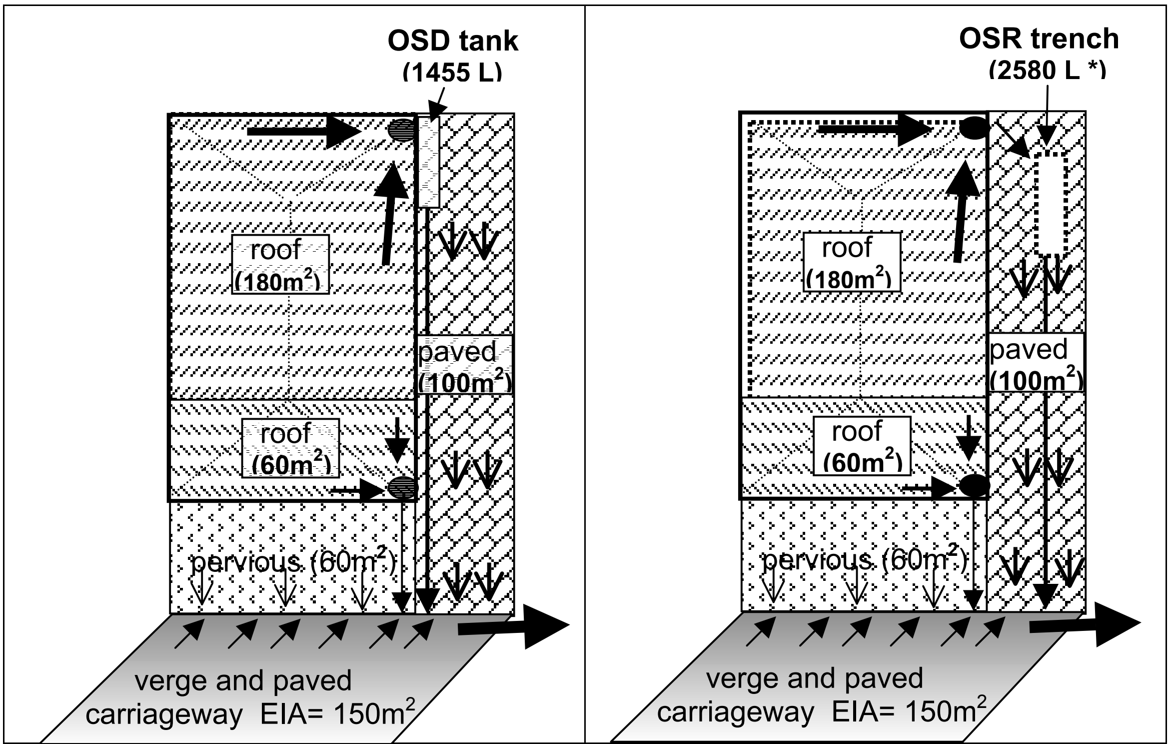
The **total** individual catchment considered in both situations includes runoff from other paved and pervious areas of the allotment, plus a 150 $m^2$ allocation of equivalent impervious area (EIA), representing the fronting nature strip and carriageway (see Figure 1).

The first output of interest is the runoff hydrograph which results from the 30-minute design storm (ARI = 5-years) applied to the development **without** detention or retention measures applied. This is shown in Figure 2 as CURVE N. Output from the site with the **detention** tank and orifice applied is shown as CURVE D; the corresponding hydrograph with the **retention** trench included is shown as CURVE R.

### 2.3 The "flooding" issue: urban landscape runoff

The observations of interest which emerge from the above considerations are, **firstly**, that the detention facility results in no reduction in peak flow discharged from the site compared to the "no control" option. This is an astonishing outcome and reflects the fact that the tank size specified for the site is too small. The **second** observation of interest is the significant reduction in peak flow (compared to the "no control" option) recorded for the retention case.

But the urban landscape comprises many such units so that the true picture which should determine our decision in the detention-retention debate is not what takes place on individual allotments but what is the output from collections of such units.




| 1a. On-site detention scenario | 1b. On-site retention scenario<br>* effective storage volume |
|---|---|

**Figure 1:** Layout of residential allotment with detention and retention measures included

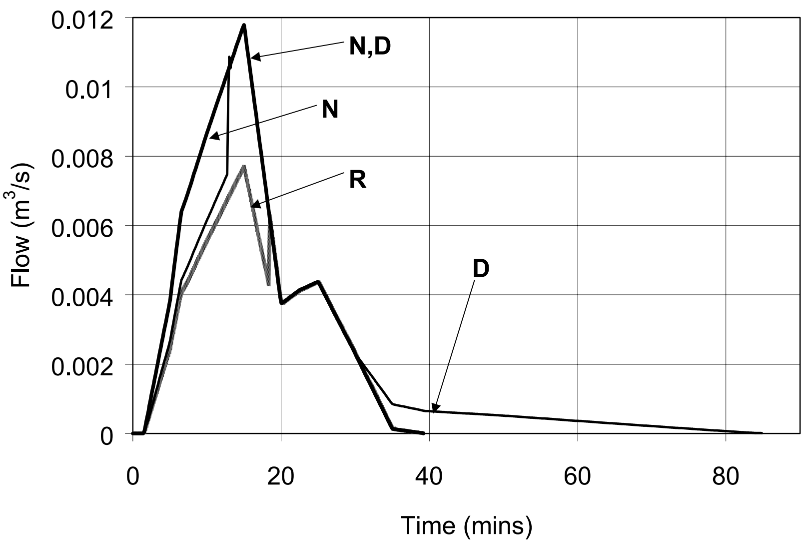



**Figure 2:** Total runoff hydrographs (using "DRAINS") for single residential allotment with no control (N), detention (D) and retention (R) measures applied

An indication of this is shown in Figure 3, again for the 30-minute (“5-years” ARI) storm in Adelaide, with 150 identical allotments, as illustrated in Figure 1, discharging "in series". Another astonishing but consistent result emerges for the **detention** case (CURVE D): the downstream flood **peak** is the same as that of the "no control" option (CURVE N) indicating no reduction in downstream flooding for the investment of some $1 300 per allotment (Planning SA, 2001b). On-site **retention** measures (CURVE R), however, deliver a 22% reduction in “downstream” flood peak for much the same cost.

The modelling described above cannot be regarded as anything more than a "skirmish" with the problem. That it does **not** represent the 'real world' situation is undisputed: the urban landscape includes a 'mix' of dwelling types - some old, some new, some large, some small; to have 150 identical house developments with 0.56 mins 'travel time' between allotments (as modelled) is most unlikely. However, it is claimed with some confidence that comprehensive analysis of real systems incorporating predicted levels of development and re-development will deliver, broadly, similar results.

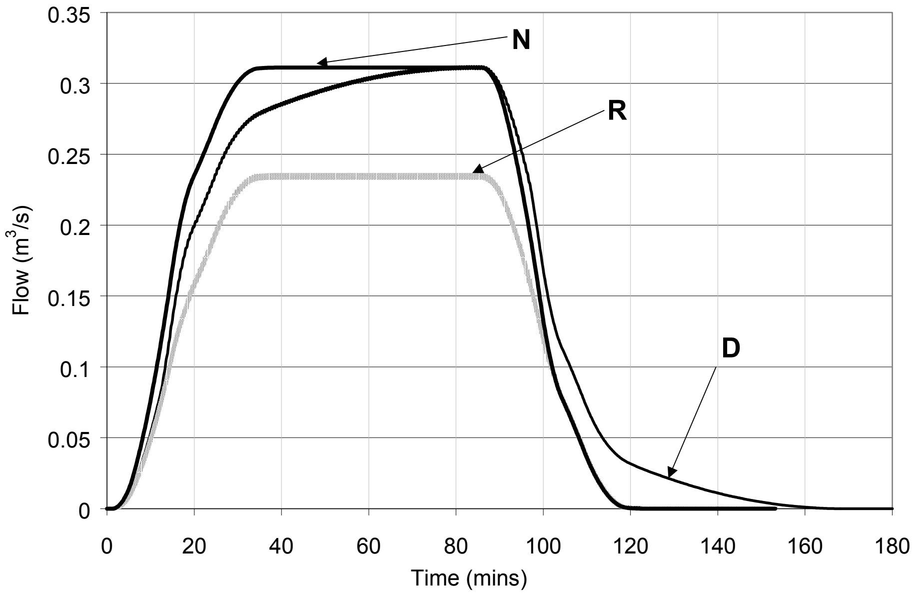



**Figure 3:** Total runoff hydrographs (using "DRAINS") for 150 residential allotments no control (N), detention (D) and retention (R) measures applied "in series": 30-min storm

## 3. RESPONSES/CONSEQUENCES OF THE DRAFT SPECIFICATION

The authors understand that the period of consultation provided before release of a final document has yielded a "swag" of responses from Councils who have independently reached similar conclusions to those above, in particular, that -

1. the on-site detention tank storages listed in the Draft Specification are too small to have any significant beneficial effect on downstream flooding;

2. OSD tank sizes needed to produce a desirable reduction in downstream flood peaks are likely to be considered "too big" (ie take up too much valuable allotment space) by householders;

3. "leaky" wells and infiltration trenches (the retention option) can achieve the desired reduction in downstream flood peaks and are likely to be acceptable to householders on the grounds of both cost and their non-intrusive nature.

Outcomes 1 and 2, above, could lead to a transfer of the OSD option into the ambit of local government where catchment-wide planning - strongly recommended in the "Guidelines" - may produce detention tank Specifications matching the stormwater management goals sought in particular Council circumstances.

But it is outcome No 3, above, in relation to on-site retention that puts the question of stormwater management in Adelaide in the 21st Century squarely into the realm of bitter and protracted local controversy. The two "sides" of this dispute are represented by the advocates of OSR on the one hand who base their case on results such as those presented in Figure 3; the opponents of this case on the other hand offer the veritable 'raft' of objections and intimidations listed in Section 4.4.3 of the "Guidelines".

The ranks of the "opponents" are made up from representatives of the building industry (Housing Industry Association and Master Builders' Association) and their comrades-in-arms, the Footings Group of IEAust, Adelaide Division. Space does not allow a comprehensive review of the objections raised by this 'lobby': suffice to say that it centres on the damage to domestic footings which they fear will surely follow the introduction of water-retaining devices such as "leaky" wells and infiltration trenches into domestic allotments of small size. Of equal concern to the 'lobby' is the cost burden which would be imposed on householders by providing "stronger" footings required to counteract the presence of retention devices.

Not all geotechnical engineers see the situation quite as clearly as the 'lobby': Dr Peter Mitchell of PPK Environment & Infrastructure, in a submission to Planning SA on the issue at hand, investigated a raft footing for a single storey domestic building and reported, *inter alia* (Mitchell, 2000)-

> *For class A and S sites, the effect of a stormwater retention device does not lead to a significant change in footing design at least for the commonly adopted single storey articulated brick veneer construction.*
> *For class M-D sites, an increase in footing size from 425 mm to 575 mm at the upper end of class*

*M-D soil movement was found to be required for a site with an on-site retention device. Although this leads to an increase in footing cost, the cost is expected to be still under average costs of footing construction in Adelaide.*

## 4. QUO VADIS?

So what is the long-suffering council engineer or technical officer responsible for stormwater management advice to the public - including developers - to make of this clash of views?

One element of the debate, which has not hitherto been heard, is that of "emptying time" of OSR devices constructed in (homogeneous) sand and sandy-clay soils ("A", "S" and "M-D" soils). The permeabilities (hydraulic conductivity, $k_h$) of these soils range from around $1 \times 10^{-4}$ m/s (sandy soil) down to $1 \times 10^{-5}$ m/s for sandy clays. The formulae derived for emptying time, **T**, of "leaky" devices are (Argue, 2000) -

- **"leaky" well:**

$$T = -\frac{4.6\,D}{4\,k_h}\log_{10}\left[\frac{\frac{D}{4}}{H+\frac{D}{4}}\right], \text{ seconds} \quad \mathbf{(1)}$$

- **gravel-filled trench:**

$$T = -\frac{4.6\,Lbe_s}{2\,k_h\,(L+b)}\log_{10}\left[\frac{Lb}{Lb+2H(L+b)}\right], \text{ seconds} \quad \mathbf{(2)}$$

where -

D = "leaky" well diameter;
b = width of trench;
L = length of trench;
$e_s$ = void space ratio, (0.35 for gravel)
H = depth of trench
$k_h$ = hydraulic conductivity

Substitution of appropriate values of these parameters into the dimensions given for "leaky" wells and infiltration trenches in the Minister's Specification leads to "emptying time" values of, generally, less **than 24 hours.**

It is inconceivable that a soil mass subject to "wetting-up" for such a short time, followed by normal processes of drying, could possibly produce the characteristic "heave" reaction of which the building/footings fraternity is so fearful.

It follows that, taking note of Dr Mitchell's advice and recognising the brief time that the devices actually retain water in a runoff event, councils can act on those sections of the Specification which relate to on-site retention of stormwater without fear of the dire consequences attributed to this technology in the "Guidelines". **This advice is conditional on adherence to the "setback" or clearance distances required in the Specification being strictly observed, and that the soil masses are fairly homogeneous.**

## 5. NOT FOR THE FAINTHEARTED!

The role of 24 hours "emptying time" in the case presented above raises yet another possibility for the use of OSR technology beyond the limits of the "A", "S" and "M-D" soils of the Minister's Specification. If 24-hour emptying (from full) could be guaranteed by design, is it possible to extend the benefits of stormwater retention, as indicated in Section 2, deep into the 'reactive' domain of the "H-E" and "E-D" soils excluded from the DRAFT Specification?

The very nature of these soils - hydraulic conductivities, $k_h$ , less than $1 \times 10^{-5}$ m/s - prevents them from transferring water any further than 0.9 m (maximum) from the point of storage in an underground device **in 24 hours**. If, in association with the positive gradient wetting front producing this penetration, there is also complete (stored) water removal in 24 hours - **by 'hydraulic' means** - then the resulting reverse flow gradient can be relied upon for some draining of moisture (back to the retention device) to occur along with significant drying of the soil mass in direct contact with it.

The suggestion offered here is, in reality, a surrogate form of on-site detention in which temporarily stored water is removed, hydraulically, over a time period (eg 24 hours) exceeding significantly that normally used in conventional OSD systems. There are two possible ways in which such a system could be employed at sites in Adelaide

- by aquifer recharge where such access is possible (see Figure 4); and,
- by 'slow drainage' pipeline where disposal opportunities exist.

The design approach needed to exploit either of these opportunities at a given site is known (Argue, 2000) and can be readily applied in the majority of Adelaide's clay-surfaced suburbs. All that is lacking is the needed audacity to do so!

## 6. CONCLUSION

The manner in which Adelaide's stormwater control/management system has evolved over the past 120 years owes much to the contributions made by many outstanding practitioners as well as an army of "unsung heroes". Engineers of the past who sought to "gather stormwater and dispose of it as completely and as quickly as possible" are criticised today because of their legacy of "bottom lands" flooding and pollution of riverine and marine waterways. But our perhaps harsh current judgements should be tempered by recognition that Adelaide remains one of the least flood-troubled cities in Australia.

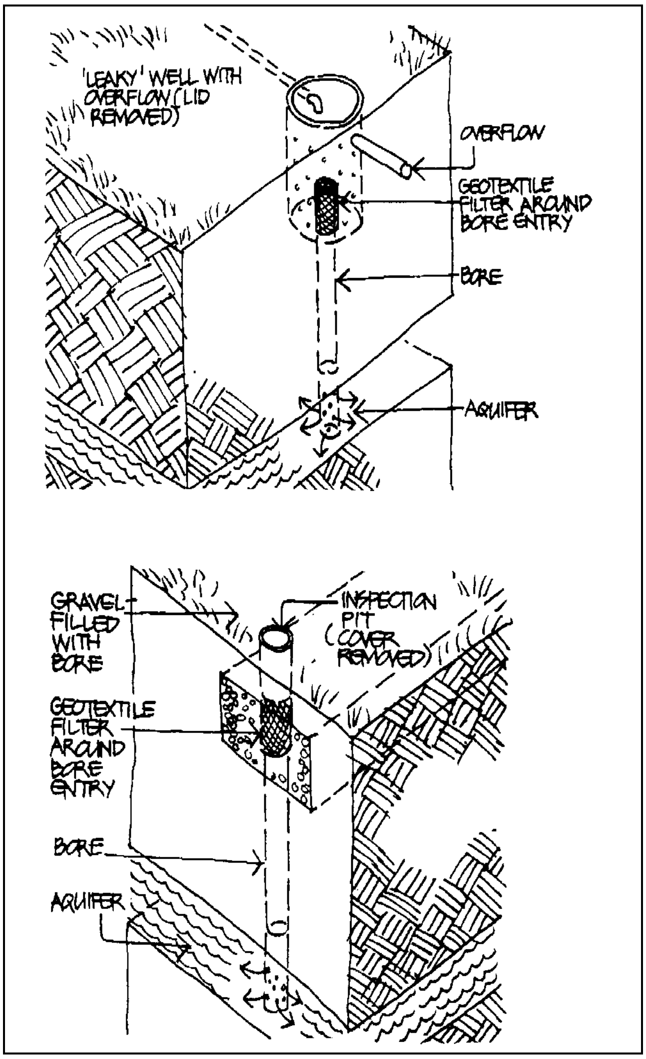



**Figure 4:** Illustrations of "leaky" well and gravel-filled trench with aquifer access giving 24- hours emptying (from full) in Adelaide.

What has been presented in this article as the "fifth landmark" - the tabling of "Guidelines" and a DRAFT Minister's Specification relating to on-site detention and on-site retention - has proved to be a worthy but incomplete attempt to provide Adelaide with a vision for stormwater management that truly reflects 'the best' that we can do.

This may result in the Minister's Specification being replaced by council specific tables based on appropriate catchment-wide analysis and planning.

Support for the retention alternative with its benefits of effectiveness (in reducing downstream flood peaks), lack of intrusion into private space and cost, stands to run the gauntlet of strenuous opposition from Adelaide's building/footings 'lobby'. The article offers evidence in support of OSR for "A", "S" and "M-D" soils in the face of this opposition. However, the argument is extended into the domain of the (reactive) "H-E" and "E-D" soils: a design approach is suggested for the 'audacious'.

"We live in interesting times": our current struggle with OSD and OSR is but a manifestation of this. And we can be sure that when the issues which we confront in the "fifth landmark" have been settled beyond dispute, that the effort will have been worthwhile and that a new and creative direction will have been set for stormwater management in Adelaide in the 21st Century.

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# Holocene wetland dynamics in response to changes in fire and climate

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**Summary**
The initiation and evolution of a Cyperaceous swamp on the Boat Harbour Creek on the Fleurieu Peninsula, South Australia over the last *c* 7500 years is revealed through palynological, macroscopic-charcoal and sediment records.

A change in sedimentation from clay to peat indicates that the swamp was initiated sometime between 7-8000 years BP. The sequence indicates changes in swamp productivity and species composition through the Holocene. High rates of peat development and the expansion of swamp species between 6200 and 4800 years BP suggests wet conditions at this time. The swamp became drier in the late Holocene; swamp species decline and some peat may have been lost through deflation. The most dramatic changes to swamp productivity and composition occur in the European period. Sedimentation rates significantly increased, due to both an increase in swamp productivity and erosional episodes, associated with the change to European land use practices.

Macroscopic charcoal documents *in situ* fire events. Disturbance by fire has been a component of the swamp ecology through the Holocene. Burning levels were consistently high during the wettest part of the Holocene. *Typha* sp. (bullrush) pollen was restricted to this phase. Aboriginal harvesting practices may be responsible for high burning levels at this time. Deliberate European burning of the swamp, recorded in local ethnohistoric records, is revealed as an unprecendentedly-high pulse of macroscopic charcoal.

The long-term record shows that wetland change has not be restricted to the recent past. A long term perspective allows for an assessment of the relative magnitude and rate of recent European land use affected changes.

## 1. INTRODUCTION

An understanding of the present day status of wetlands in relation to recent responses to European disturbance is required to guide management strategies for the maintenance of their biodiversity and environmental values, under changing climate conditions.

The present day status of wetlands can only be appraised by a range of questions whose answers lie in the recent and medium term past. These questions include: (1) what have been the site's responses to European-induced disturbances, (2) how stable are the sites (3) how representative of pre-European conditions are the sites, (4) how have the sites responded to past disturbances and (5) how have the sites responded to past climate changes?

Some wetlands, peatlands in particular, retain a history of their development in the form of macrophytic remains, gross stratigraphy and microfossils such as pollen and charcoal. These features provide information that could only otherwise be uncovered by monitoring and ecological studies which span years, decades or centuries.

This study considers the history of the Boat Harbour Swamp, a peatland swamp, in the Fleurieu Peninsula in South Australia, in order to provide insight into swamp responses to environmental change and human and natural disturbance in the European and pre-European historical periods. The swamps of the Fleurieu Peninsula have considerable conservation value and contain threatened plant communities and provide habitat for threatened fauna. An estimated 42% of plants of conservation significance on the Fleurieu Peninsula are confined to upland freshwater swamps (Lang and Kraehenbuehl, 1987). Draining, burning and vegetation clearance for agricultural purposes has resulted in only 25% of the original estimated 2000 ha of pre-European swamp area. (Duffield, 2000). This study provides a temporal context necessary for making policy decisions on the management and conservation of these important ecosystems in the Fleurieu Peninsula.

## 2. BOAT HARBOUR CREEK SWAMP

The Boat Harbour Creek swamp is a cyperaceous and shrub peatland, which in-fills a relatively gentle valley on the highland plateau of the Fleurieu Peninsula in South Australia (Figure 1) (35$^{o}$ 34'S, 138$^{o}$18'30''E, elevation 290 m. a.s.l.). The swamp is topogenous, being dependent on surface run off and ground water to maintain waterlogged conditions. A tributary of the of the Boat Harbour Creek enters the swamp 2.5 kilometres from its headwaters being fed by catchment area of 103 ha before reaching the core site. *Baumea rubiginosa, B. tetragona, Empodisma minus, Shoenus* spp., *Acacia retinoides, Leptospermum continentale* and *L. lanigerum* are the dominant swamp flora. The soils of the swamp are dark brown sandy to clay loam

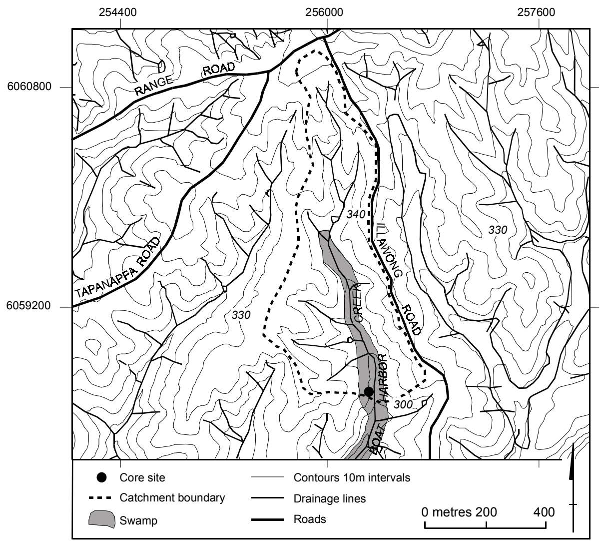


**Figure 1.** Core site in relation to swamp and local catchment topography.

with a paler coloured and gravelly A2 horizon. The soils of the surrounding catchment are grey-brown sandy loams overlying an ironstone gravelly yellow-brown to red clays, formed on highly weathered and kaolonised metasandstones and metasiltstones. The site receives an average annual rainfall of 843 mm with a winter and summer rainfall of 361 mm and 86 mm respectively. The mean annual temperature is $13.9^{0}$C (values from ANUCLIM1.2 regional climate models).

The native vegetation surrounding the swamp was 'rough grazed' by sheep from about *c.*1840 to the early 1950s. The land through this time was subjected to periodic firing, at approximately five year intervals, to promote grass palatable to stock (Williams, 1991). The swamp was delineated in the 1884 survey of the area and marked as 'tea tree bushes'. In 1953 the catchment was cleared of its native vegetation cover, sown to perennial ryegrass and subterranean clover and continued to be used for sheep and cattle grazing. Since clearance, superphosphate and trace elements have been regularly applied to the catchment. Landowners recalled that that following native vegetation clearance in the catchment, swamp vegetation noticeably altered. The Leguminosae components, most notably *Viminaria juncea* and *Acacia retinoides* greatly increased in number. The Boat Harbour Creek has flowed continuously without drying over the last 50 years except for 1962 when it almost completely dried out except at a single swamp along it's course.

## 3. METHODS

A 200 cm long core, BH2, was taken using a Russian Peat corer from the middle of the swamp. Sub-samples of sediment were taken at 5-10 cm intervals along the core for fossil pollen and spore and micro charcoal extraction. A second core, BH3, was taken adjacent to BH2 to provide additional material for radiocarbon dating. Macroscopic charcoal content was analysed at 2-5 cm intervals. Fossil pollen was prepared using standard methods of preparation (Faegri *et al.*, 1986). Macroscopic charcoal was prepared using a method developed by McDonald *et al.* (1991). Microscopic charcoal was counted using the point count technique developed by Clark (1982) on slides prepared for pollen examination. Pollen counts are expressed as percentages of the sum of all aquatic and swamp fringe taxa. Numerical zonation using optimal splitting by sums of squares was performed on pollen data to identify sections of similarity and difference in pollen spectra. Zones represent times of relative stability, while zone boundaries indicate significant change to another state.

Radiocarbon at the Quaternary Dating Research Centre of the Australian National University and lead-210 dating were carried out CSIRO Land and Water. Microfossils were also employed as a chronological markers.

## 4. RESULTS AND INTERPRETATION

### 4.1 Chronology

Radiocarbon dating was carried out on both the soluble and insoluble fractions of NaOH-treated organic material. The insoluble fraction produced an unlikely chronology with age inversions, which were not substantiated by the sediment or pollen record. However the soluble fraction resulted in a near linear increase of ages with depth. An additional radiocarbon date was obtained from an adjacent core, BH3, and used to compile the chronology of BH2 following stratiographic matching using the uppermost clay band common to both cores.

Nineteen sediment samples were taken from the top 65cm, and two from near the base of the core, for $^{210}$Pb dating. $^{210}$Pb results were modelled using the constant rate of $^{210}$Pb supply (CRS) model, a variable accumulation rate model. The CRS model has been considered to be the most appropriate for lead dating of organic rich matter (Appleby and Oldfield, 1992) where the $^{210}$Pb concentration does not monotonically decrease. Depth has been calculated as cumulative ashed sediment to eliminate the effects of compaction and variable sediment grain size, both of which can affect porosity. The resultant age-depth curve is shown in Figure 2. It suggests that sediments above 24 cm are younger than 80 years old. The change in slope at 12

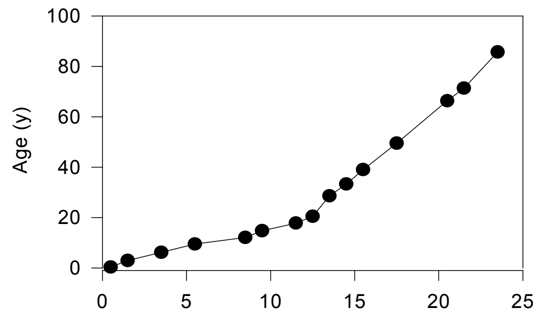


**Figure 2:** Age-depth plot for core BH2 derived from CSR modelling of $^{210}$Pb dates.

cm indicating two distinct sedimentation rates have been in operation over the last 80 years.

European pollen types, *Rumex, Plantago Cirsium* and *Pinus*, were found in the top 35 centimetres indicating these sediments were laid down post the time of European settlement.

The source of macroscopic charcoal in sediments is from burning events in the swamp itself or in the catchment surrounding the site. Correlation of its phases of abundance with known local burning events is possible. The whole catchment was cleared and burned in 1953. There is an uniquely large macroscopic charcoal peak at 22 cm, which just precedes the rise in grass pollen, a decline in *Eucalyptus* pollen and rise in Pea type-1 pollen (Bickford, 2001). Given these correlations and the unprecedented size of this charcoal event it is probable that this peak marks post-European sediments and possibly catchment clearance in 1953.

The various chronological markers used to derive the age model of sediments are presented in Figure 3. The age model adopted for the BH2 core was developed using linear interpolation between samples and is shown on Figure 4.

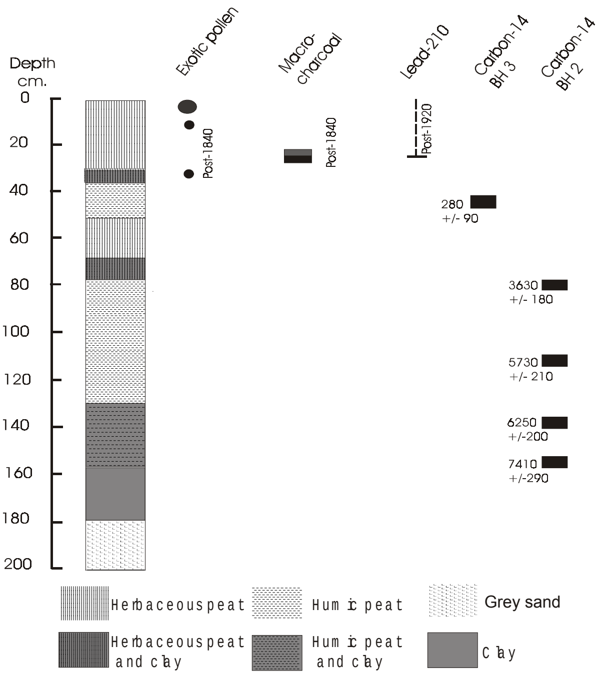


**Figure 3:** Stratigraphy of core BH2 and the radiocarbon, lead-210 and chronological markers used to derive an age model.

## 4.2 Sediments and microfossils

The pollen and charcoal diagram summarising microfossil data is presented in Figure 5. The zones it displays are as follows:

### 4.2.1 Early to mid Holocene swamp initiation: Zone B-1 >7410 - 6250 years BP

Sediments and pollen indicate that the Boat Harbour Creek swamp began to form some time between 7-8000 years BP. The lower-most sediments are clays, containing little organic material. Cyperaceae pollen in these sediments is less abundant than in later organic-rich ‘swamp’ sediments; comprising 20% of the total pollen sum compared with between 35 and 65% of later sediments. Sediments contain only small amounts of pollen of the swamp-margin species, *Leptospermum* and *Acacia*. Local conditions were clearly moist at this time, as indicated by the presence of *Myriophyllum, Villarsia* and *Stellaria* pollen, but not wet enough for peat preservation. Microscopic and macroscopic charcoal levels are relatively low. The terrestrial vegetation in the catchment was characterised by a *Eucalyptus* woodland with a sclerophyllous understorey (Bickford, 2001).

### 4.2.2 Mid-Holocene swamp expansion: Zone B-2 6250-3500 years BP

The organic content of sediments greatly increases in this phase and sedimentation rates are substantially higher than in the swamp initiation phase. The pollen spectra shows marked changes; Cyperaceae pollen increases in representation, *Acacia* levels decline, *Goodenia* almost disappears while *Leptospermum* increases. This appears to be a period of reed swamp establishment, lateral expansion and colonisation by the swamp-fringe shrub species *Leptospermum*. *Typha* is present through out the zone. Its present day ecology indicates that water levels may have been higher than present but not deeper than 1.5 metres (Gott, 1982; Dodson, 1977), -although it can be deduced that water levels were probably not greatly deeper than at present as *Carex*-type and *Baumea*-type Cyperaceae do not decline in number (Dodson and Wilson, 1975). The terrestrial vegetation in the catchment was characterised by a wet heath of *Banksia*, *Leptospermum* and swamp *Allocasuarina* (Bickford, 2001). Macroscopic charcoal levels fluctuate greatly in this phase. High concentrations are likely to have an *in situ* origin and indicate burning of the swamp itself. High levels of microscopic charcoal have been used as evidence for Aboriginal wetland use in other sites in Australia (Head, 1988). It is possible that peaks represent deliberate Aboriginal burning of the swamp. The presence of *Typha* pollen in this zone strengthens this suggestion. *Typha* was a staple in the diets of South Eastern Australian Aborigines, and swamp firing in the summer months was carried out to assist the harvesting of its roots (Gott, 1982; Clarke, 1988).

### 4.2.3 Late Holocene Zone B-3 3500- ~250 years BP

From around 3500 years BP a drier period is evidenced. The organic content of sediments declines and peats show less humification than those in zone B-3, except for a brief return of humic dominated peats between 50 and 37cm. The sedimentation rate is lower than in the mid-Holocene suggesting either lower swamp productivity or possible loss of sediments through drying and deflation. The dating of this upper part of the core is not sufficient to resolve the possible scenarios. *Carex* type-Cyperaceae declines before showing a rise at the top of the zone and *Baumea* type Cyperaceae values fluctuate. *Typha* pollen disappears. *Acacia* is more prevalent than in the previous zone and *Leptospermum* remains largely unchanged from the previous zone. *Goodenia* once again enters the swamp. The catchment vegetation changes dramatically from wet heath to *Eucalyptus* woodland (Bickford, 2001). Microscopic charcoal values are constantly low through this zone while macroscopic concentrations vary but do not reach the high concentrations of the high levels attained in the previous zone.

### 4.2.4 Early European: Zone B-4: 250 years BP- *c* 1900

The post-European sediments are organic rich herbaceous peats, except for an incursion of clay sediments at around 28 cm. The clay incursion could be representing increased erosion in the catchment during the burning and grazing phase of European settlement or an effect of vegetation clearance in the catchment in 1953. Sediment accumulation rates are significantly higher than in previous zones and vary within the zone. Cyperaceae still appear as major components of the swamp however marked changes to the swamp flora are seen in this phase. *Acacia* pollen dramatically increases in abundance probably indicating its expansion on the site. Unprecedented high levels of microscopic charcoal and the highest concentration of macroscopic charcoal appearing in the core occur in this zone. *Acacia* germination is encouraged by fire, thus its expansion could be a response to increased fire disturbance.

### 4.2.5 Late European: Zone B-5 *c* 1900 - present

Sediments continue to be organic rich herbaceous peats. The upper most zone is distinguished by a clear shift from *Acacia* to *Leptospermum* strongly dominating the pollen spectrum. Microscopic and macroscopic charcoal levels decline from the previous zone.

## 5. DISCUSSION AND CONCLUSIONS

Swamp sediments, pollen and charcoal provide an environmental and ecological history of the Boat Harbour Creek peaty-swamp. The study primarily indicates that the swamp has been a dynamic environment since its inception sometime before 7500 years BP. The swamp showed responses to regional Holocene climate changes. Swamp initiation was just before the period of maximum Holocene precipitation in South Eastern Australia (about 7000-6000 years BP). As such it is in keeping with a major phase of peatland development in southern Australia, including those in the south-east of South Australia (Kershaw *et al*., 1993; Dodson and Wilson, 1975). Later responses to regional climate are also seen in the phase of rapid peat production around the maximum period of Holocene precipitation and a reduced production phase with possible loss of peat sediments in the later Holocene phase which was characterised by drier and more variable climatic conditions. It could thus be expected that these environments will be particularly sensitive to possible future greenhouse-affected changes in regional precipitation and temperature.

The most dramatic changes to the swamp flora, in rate, kind and magnitude, are shown to have occurred in the time since European settlement. Given that climate has been relatively constant through this time it can be deduced that responses have been directly related to activities of European people. The pollen record indicates that the current day swamp is different from its pre-European state. Successional processes occur in the recent European period, first with *Acacia* expansion, and its later replacement by *Leptospermum*. These changes are most likely to be driven by intensified European fire regimes and hydrological changes related to vegetation. It is likely that a new stable state has not been found and these environments are still in relative flux.

Such information provides grist to the mill for discussion of what rehabilitation and management goals should be. Should goals be directed toward maintenance of what we have now, or the ecology of 1836 or consider future climate change scenarios and manage for ecosystems that were under potentially analogous climates? This study additionally shows that swamps have evolved with anthropogenic disturbances, however aboriginal burning did not have the dramatic impact on wetland ecosystems that European activities have had.


## 6. ACKNOWLEDGEMENTS

We thank Peter Wallbrink and Gary Hancock, CSIRO Land and Water for the radionucleotide of sediments and John Chappell from the radiocarbon dating centre at the Australian National University for carbon dates.


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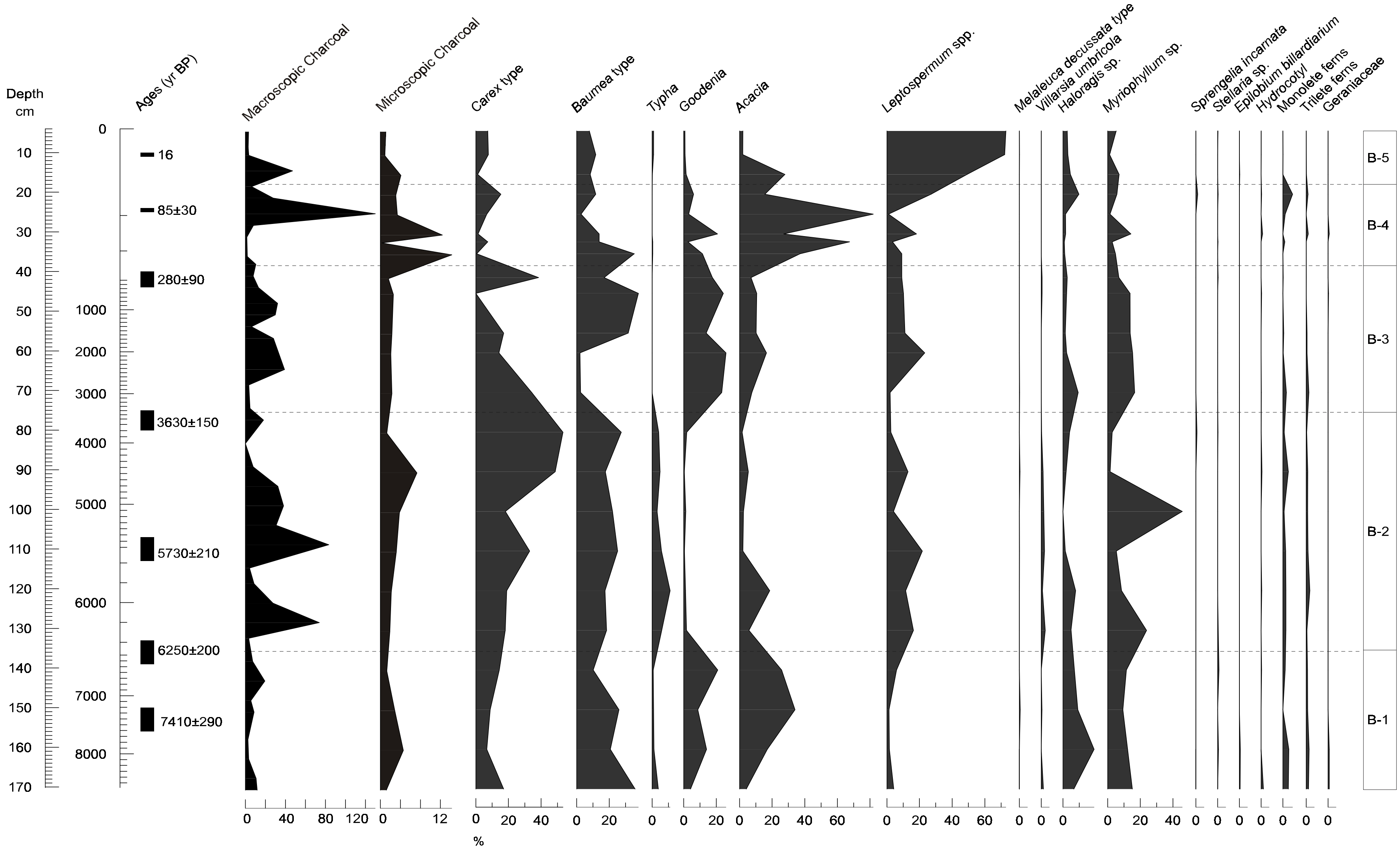


**Figure 4.** Pollen and charcoal diagram: core BH 2, Boat Harbour Creek Swamp**.**

# The development of surface water resources in Australia

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**Summary**
Very little development of major dams occurred in Australia before 1900, and most of the storage capacity in major dams was constructed after 1950. The total storage capacity of all major dams in Australia at 1990 was some 78.9 $km^3$ with New South Wales and Tasmania each having more than 30% of the total. The three main driving forces for major dam construction were urban water supply, irrigation and hydropower generation. Major changes in the 1990s were a change away from the political use of water as an agent of regional development, and a change to less construction of new storages and more attention to management of existing water resources.

## 1. INTRODUCTION

The 20th Century will be remembered as the century of major water resources development in Australia. In 1900, the population was 3.8 million and the total storage capacity in all major dams was 0.25 $km^3$ (250 000 ML). By 1950, the population had more than doubled to 8.3 million, and the water stored in major dams had jumped to 9.5 $km^3$. By 1990, the population had doubled again and was just under 19 million, while the water stored in major dams had increased enormously to 78.9 $km^3$.

The second half of the century was the period when most of the storage capacity of major dams in Australia was constructed. Some 87% of the total storage capacity (at 1990) was constructed after 1950. It is difficult to comprehend that the primary objectives of the Australian Water Resources Council, established in 1962, were to make a comprehensive assessment of the nation's water resources, and to extend measurement and research to provide a sound basis for the planning of developments. The major period of water resources development in Australia was well under way when the Council was established.

## 2. THE DEVELOPMENTS

It is not of much use to measure water resources developments in terms of number of dams. The number of farm dams of small capacity, used as stock watering points, is very large, but the total storage of water in all of those dams is relatively small. Total storage capacity of constructed dams is a better measure of overall development.

The dams which are considered in this paper are those that meet the definition of a large dam by the Australian National Committee On Large Dams (ANCOLD). The 1990 ANCOLD Registrar of Large Dams shows that the total storage capacity of all defined "large" dams in Australia at 1990 was 78.9 $km^3$, or 78.9 million megalitres. An informal unit of storage capacity commonly used in Australia is the "Sydharb", which is the amount of water in Sydney Harbour, about 530 000 megalitres or roughly half a cubic kilometre of water. So the total capacity of all major dams in Australia at 1990 was 78.9/0.53 = about 150 Sydharbs.

The major development after 1950 gives an impression of a brief period of development; however, this is not correct. Figure 1 shows a histogram of the amounts of storage capacity constructed in each decade from 1860 to 1990. The growth in the amounts per decade has been exponential, and this is best shown with the vertical axis plotted on logarithmic scale, as in Figure 1. It can be seen that there has been a relatively steady exponential growth from the start of major dam construction in the mid-1800s, through to a peak in the decade 1970-1980, and a decline at the end of the available data.

There are some points of particular interest in Figure 1. The dip in the general rate of increase that occurs between 1910 and 1920 coincides with World War 1. There is a similar dip between 1940 and 1950 coinciding with World War 2. Even with two world wars affecting the trend, the exponential growth in the rate of construction of storage capacity in major dams has been relatively steady over a period of almost 150 years.

The dip after 1980 is probably an indication that the rate of construction of storage capacity will continue to decline in the future as unused major dam sites become scarce and costs of future developments rise.

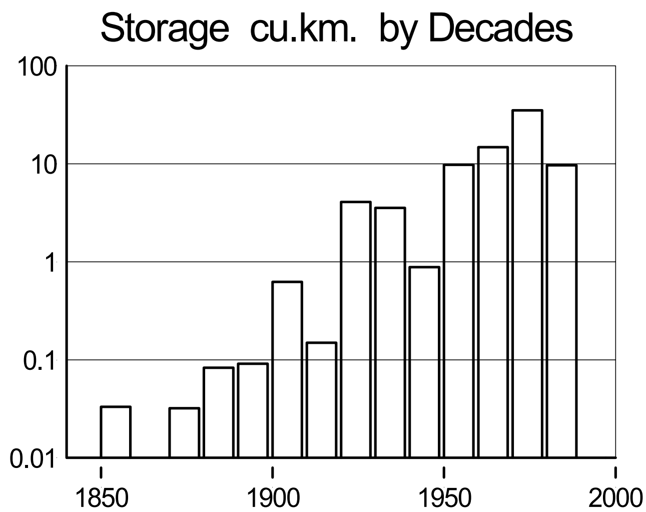


**Figure 1:** Construction of storage capacity in major dams by decades.

The total storage capacity is not uniformly distributed among the States and Territories. Table 1 shows the distribution of the 1990 total of 78 919 400 megalitres (78.92 $km^3$) among these regions. The total capacity in New South Wales includes the capacities of dams in the Snowy Mountains Scheme, as well as the dams providing water to Sydney (the largest city in Australia) and the irrigation dams.

**Table 1:** Distribution of storage capacity in 1990

| State/Territory | Total Capacity megalitres |
|---|---|
| New South Wales | 25 389 300 |
| Tasmania | 24 167 000 |
| Victoria | 12 226 000 |
| Queensland | 9 459 200 |
| Western Australia | 7 011 300 |
| Northern Territory | 275 200 |
| South Australia | 266 800 |
| Australian Capital Territory | 124 600 |
| TOTAL | **78 919 400** |

## 3. THE TOP TEN

The Snowy Mountains Hydroelectric Scheme is an icon of water resources development. It was constructed mainly in the two decades between 1950 and 1970. It is regarded by most Australians as a major water resources development, but a single dam in Tasmania, The Gordon River dam, has a storage capacity that is larger than the combined storage capacity of all dams in the Snowy Mountains Scheme. Table 2 shows the 10 largest dams (by storage capacity) in Australia. There is a mixture of applications of these storages among urban water supply (Warragamba), hydroelectric power generation (Gordon R. and Lake Pedder) and irrigation.

**Table 2:** Ten largest storages in Australia

| No | Name | Capacity $km^3$ | State |
|---|---|---|---|
| 1 | Gordon R. | 12.45 | Tas |
| 2 | Ord R. | 6.11 | WA |
| 3 | Eucumbene | 4.80 | NSW |
| 4 | Dartmouth | 4.00 | Vic |
| 5 | Eildon | 3.39 | Vic |
| 6 | Hume | 3.04 | NSW |
| 7 | L. Pedder | 2.96 | Tas |
| 8 | Warragamba | 2.06 | NSW |
| 9 | Burdekin Falls | 1.86 | Qld |
| 10 | Menindee Lakes | 1.79 | NSW |

## 4. THE OLDEST MAJOR DAM

The 1990 ANCOLD register of large dams in Australia is the source of most of the information given in this paper. The records in the register are arranged in chronological order, and the first entry is the Lake Parramatta Dam in the western suburbs of the Sydney conurbation. This was the first "large" dam (in ANCOLD terms) built in Australia. In 1997, the Lake Parramatta Dam was honoured as a National Engineering Landmark by the Institution of Engineers, Australia. The dam ceased to be used for water supply in 1916, but is still structurally sound. It is a monument to the origins of water resources development in Australia.

## 5. THE DRIVING FORCES

There were 3 main applications driving the development of water resources during the past 150 years. These were urban water supply, hydropower generation and irrigation.

### 5.1 Urban water supply

Those attending this conference will have lived in an era in which relatively cheap and abundant water of good quality was commonplace for most urban dwellers in Australia, albeit with some urban locations with other conditions. This abundant supply was not the normal circumstance in earlier periods of the nation's development, and will probably not last indefinitely into the future. Because of the large variability of the Australian climate between floods and droughts, there is a need for much larger storage capacity per capita in Australian urban water supply dams than in those in Europe and North America, so the reliable supply of water has come at a cost. The major period of water resources development in the 2$^{nd}$ half of the 20$^{th}$ century included the construction of some major urban water supply dams. At the start of the 21$^{st}$ century, there is already an increasing emphasis on demand management to reduce or delay the need for more storage.

### 5.2 Hydropower generation

There are two main areas of hydropower generation in Australia – Tasmania and the Snowy Mountains region. The driving forces of these two areas of development were quite different. Tasmania lacks the coal resources of Queensland, the iron ore of Western Australia and the manufacturing bases of New South Wales and Victoria. Its main resource has been cheap hydroelectric power. The result is that a small State with about 3% of the population has some 30% of the total storage capacity of the nations large dams. Most of this storage capacity is in hydropower storages, including the largest storage in Australia, the Gordon River Dam.

The Snowy Mountains Hydroelectric scheme was built for significantly different reasons. Although proposals for redirecting and harnessing the waters of the Snowy, Tumut, Murray and Murrumbidgee Rivers began in the 19$^{th}$ century, the main driving forces of the actual construction were the needs for postwar reconstruction after World War 2, and national development to redirect workers from wartime to peacetime production and to create work for a large number of migrants from Europe. Construction began in 1949 and was largely completed by 1970. The Snowy scheme is the archetype of the political use of water resources development for regional development and postwar reconstruction.

### 5.3 Irrigation

Irrigation consumes some 70% of all water used in Australia and is the main support of the economy of many regions. The political use of irrigation for regional development is a particular feature of water resources development in Queensland, New South Wales and Victoria. The Murrumbidgee Irrigation Area in New South Wales was established in 1908. The ongoing economic success of this region can be seen in the dried and/or canned fruits on supermarket shelves in most of eastern Australia. Cotton growing in the Namoi River Valley in New South Wales and at Emerald in central Queensland has resulted in greatly enhanced economic activity from water resources developments in those areas. It would be wrong to imply that all such developments have been successful. The Ord River development in Western Australia and, to a lesser extent, the Humpty Doo project in the Northern Territory are testament to the difficulties of developing irrigated agriculture in the tropical north of Australia.

Powell, in his 1991 documentation of the history of water developments in Queensland, reports an interesting episode in the many efforts towards development of the waters of the Dawson River. In 1926, the Queensland Government applied to the Development and Migration Commission to make development of the Dawson River for irrigation an "agreed undertaking" for the promotion of immigration to Australia under an agreement with Britain. It is interesting to find that such a Commission and agreement with Britain existed at the time. Efforts to develop the waters of the Dawson River continue to this day.

## 6. CHANGING ATTITUDES TO WATER RESOURCES DEVELOPMENT

Public attitudes to water resources changed substantially during the 20th century. In the 1930s, the Idriess and Bradfield proposals for diverting water from the coastal rivers of Queensland to develop semiarid inland regions were widely accepted and applauded. In particular, the Bradfield scheme became established in the minds of the Australian population as an icon of the potential for development of the country's natural resources. Despite adverse reports by Nimmo in 1947, Burton in 1961 and by a Study Consortium of Queensland consulting engineers in 1984, and despite any evidence of economic viability, the icon persisted.

In the 1960s, when the writer worked in the Secretariat of the Australian Water Resources Council, the Commonwealth Government had both a Department of National Development and a Department of Northern Development. This was clear evidence of the pro-development sympathies of the time.

In 1969, the U.S.A Congress passed the National Environmental Policy Act. Soon after in the early 1970s, the Commonwealth and State Governments of Australia all passed legislation requiring that environmental impact assessments be made in the planning of major projects including the development of water resources. Controversies over water developments such as Lake Pedder in Tasmania raised an anti-development sympathy that was in marked contrast to the pro-development sympathies earlier in the century. Near the end of the century, there was a major change away from government investment in water projects for development purposes, and an increasing emphasis on commercialisation of the water industry.

The most significant document concerning water resources in recent years is the *Report of the Working Group on Water Resources Policy to the Council of Australian Governments* in February 1994. The emphasis at that time was clearly on the commercialisation of the water industry, with commercial pricing of water, allocation and trading of rights to water, water being employed in higher value uses, and more transparency in government subsidies and payments. The reforms of the water industry set out in this COAG document are in marked contrast to the use of water as an agent of development through the first three-quarters of the 20th century.

## 7. THE FUTURE?

In the 20th century, the population of Australia increased from about 3.8 million to about 19 million, a fivefold increase. Present indications are that the population will stabilize at less than 30 million sometime in the next half-century. The substantial reduction in the rate of increase of the population is one reason why there will be a much reduced rate of construction of major storages in the foreseeable future.

The decade 1970-1980 was the time when the peak rate of construction of water storages occurred, with less than one-third of the peak rate in the following decade. The last decade 1990-1999 saw two noteworthy changes.

First, there was a major change away from the political use of water as an agent of regional development towards commercialisation of the water industry. It has been interesting to see the renewed willingness of State and Commonwealth Governments to invest large amounts of public monies in railway infrastructure after a long period of little interest in such investment, while the interest in water resources infrastructure suddenly declined. Perhaps in the distant future there might be a resurgence of investment in water resources in the same way as railways have come back into favour.

The second change in the immediately past decade has been the increasing attention to detailed management of water resources as the rate of construction of new storages has declined. It seems a safe projection that the next few decades will see increasing professional activity by water engineers in management of established resources in the same way that the period after 1950 saw increasing activity in the development of new resources.

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# The Great Artesian Basin, Australia - turning understanding into outcomes

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**Summary**
Although large volumes of water are stored in the Great Artesian Basin (GAB) only a relatively small amount can be used on a sustainable basis. The availability of GAB water, originally from natural springs and later from bores, has had a major influence on the natural and cultural history of the Basin. For more than a century the pastoral industry in the Basin has relied on access to artesian water from the GAB and developed management practices that rely on delivering water to stock through open drains. However, the volume of water which flows from the hundreds of uncontrolled GAB bores into bore drains far exceeds that required by stock and causes other land-use problems. This problem was recognised more than seventy years ago and since that time sporadic efforts have been made to reduce the waste and improve the management of water distribution.

In the past, a poor understanding of the GAB and the inadequacies of the technology of the times often limited the effectiveness of management decisions. The remoteness of the Basin and the wide distribution of the bores has meant that the economic and cultural significance of the wasted water and the impacts of poor management have not been acknowledged by decision makers or opinion leaders in the wider community. This has not engendered the will or urgency among politicians or water managers to address the problem and has led to the unsustainable situation that the GAB is now in.

The Great Artesian Basin Consultative Council formed in 1997 produced a Strategic Management Plan (SMP) that suggests a comprehensive framework to achieve sustainable management of the Basin over a fifteen-year period. The SMP is based on the premise that water users, Governments and other stakeholders have important roles to play in infrastructure renewal and the management of the Basin. The SMP says that most of the responsibility for sustainable Basin management rests with water users. However, State and Commonwealth Governments and other stakeholders have key roles in reforming current management practices.

The SMP suggests that the implementation of the plan across the Basin must be based on shared values, investments and partnerships between governments, water users and other interest groups. The challenge is to reconcile the issues, understanding and expectations that drive current management practices in the pastoral industry with the bureaucratic issues, understanding and expectations that drive various State and Commonwealth Departments.

It is conceivable that the greatest threat to achieving the sustainable management of the Basin comes from governments' unwillingness to undertake appropriate institutional reform rather than from pastoralists' unwillingness to reform their management practices. It will be very interesting to see if community leaders and decision makers have the will to work cooperatively and remain focused long enough to ensure that the partnerships and shared investments really work and achieve the on-ground changes required over the next fifteen years.

## 1. INTRODUCTION

The Great Artesian Basin is recognised as one of the world's largest artesian aquifers. It is estimated to hold about 8 700 GL of water, which is around 17 000 times the volume of Sydney Harbour. The GAB underlies nearly half of inland Australia. That constitutes approximately one-fifth of the Australian continent; most of which is classified as arid or semi-arid (Perry 1967). The GAB is a confined groundwater basin comprising a complex multi-layered system of water-bearing sandstone strata (aquifers) confined by largely impervious shale sediments. Water recharges into exposed water bearing aquifers from rainfall events mainly on the dividing range in Queensland and New South Wales. These aquifers are laterally continuous across the extent of the Basin and exist up to 3 000 metres below the surface in the central region. The water in the aquifers moves very slowly mainly

[1] *The views expressed in this paper are those of the authors and not necessarily those of the Arid Areas Catchment Water Management Board or the Great Artesian Basin Consultative Council.*

from east to west and is estimated to be more than two million years old near the western margin. While variable in quality, the water yielded by the aquifers is predominantly fresh, and in most areas under sufficient pressure to provide a naturally flowing source when tapped by the drilling of bores. Natural surface outflows occur from artesian springs especially near the western margins of the Basin (Habermehl 1980).

The availability of GAB water, originally from natural springs and later from bores, has been a key factor in both the natural and cultural history of the Basin. Over hundreds of thousands of years, complex biological communities developed in and around the natural springs from the GAB. Most of these water dependent communities are isolated in the small permanent wet areas around the springs in an otherwise arid landscape where the evaporation rate far exceeds the annual rainfall. During frequent dry periods, these wet areas provide an invaluable refuge for native species and more recently feral and domestic animals. Ecosystems that have evolved in the arid landscapes over much of the Basin persist without permanent water in cycles of infrequent rains and long hot dry periods (Morton et al, 1995). However, spreading water from GAB bores across the landscape to provide watering points for domestic stock, and inadvertently feral animals, has effected major changes in floristics and animal populations in many of the natural communities in the Basin (Landsberg et al, 1997).

The movement pattern of people across much of Central Australia was determined for many thousands of years in part by natural flows from the GAB. While other sources of water were utilised in areas devoid of mound springs, the earliest human inhabitants found few alternatives to these scattered sources of permanent water as the ephemeral surface flows from infrequent rains dried in the hot desert sun. Because of their importance to the survival of indigenous people, natural springs from the GAB provide a focus for important cultural values to many indigenous communities in Central Australia (Harris 1981).

Based on their discovery of the GAB springs, early European explorers such as John McDouall Stuart, and Egerton Warburton suggested a vision of unlimited artesian water in Central Australia. The tracks along these life-giving springs first identified by indigenous people, and later mapped by European explorers were soon followed by camel trains, the overland telegraph, the Ghan railway and, of course, modern four-wheel drive explorers. However, natural flows were very scattered and most were of limited quantity and quality. Not until bores were drilled into the GAB late in the nineteenth century was the value of the Basin to all human development in Central Australia actually realised.

The first artesian bore was drilled near Bourke in 1878. This sparked scientific explorations in the 1880s that suggested artesian water could be found across most of central Queensland, and North-western New South Wales. LC Russell, the NSW Government Astronomer at the time, suggested "inexhaustible subterranean reservoirs" of underground water existed in Western New South Wales to be used for livestock, irrigation and farming to transform the country and overcome drought. The first successful water bore in Queensland was drilled near Barcaldine in 1887 yielding 13 ML/day. (Cox and Barron, 1998). Most bores in South Australia into the GAB were drilled by the Government. Searches of records of drilling in South Australia are inconclusive but indicate that the earliest bores were drilled in the mid 1880s. For example, Hergott No.2, a railway bore, was drilled in 1886.

Following the success of the early drilling, various private and government interests formed to 'develop' the extensive groundwater resource. The major landholders in central Queensland and Western New South Wales such as James Tyson and Sir Sidney Kidman invested heavily in bores during the drought of the 1880s and 1890s (Noble et al, 1998). Bores were not only drilled to supply the pastoral industry, but to provide water for towns and transport corridors such as railways and sock routes.

Toward the end of the 19th century, the South Australian Government had recognised the economic benefits offered by the GAB. The Parliament began to prescribe watered-routes and invest public funds in sinking bores across the desert from the Territory and the Eastern States to deliver goods to the industries and docks of Adelaide. In the 1890s bores were sunk near mound springs to develop a stock route to Oodnadatta and then on to Alice Springs. Later more bores were sunk along this route by the government to extend the railroad. However, the biggest investment of public funds was made to sink bores along stock routes from Queensland and New South Wales. In answer to a question to the Legislative Council in August of 1892 concerning the development of the Oodnadatta to Alice Springs stock route the Hon Mr. Angas said:

*It is the intention of the Government to carry out improvements to enable cattle which cannot now travel, to be brought to market and to afford similar facilities on the North West route as have been provided in the North east routes from Queensland and New South Wales* (State Parliamentary Papers 1889 to 1905).

In 1896 a map showing water conservation works on stock routes both completed and underway was produced for Parliament by the Engineer in Chief's Department (SA Government 1904). The northern stock routes played a vital role in the development of the wool and cattle industry and all human activity through central Australia for many years. By the end of the 19th Century, continued drilling and investigation established the extent of the artesian water across the Basin and bores were drilled on pastoral runs for the management of stock as need and cost dictated (Yelland, 2000). By 1918 more than 1500 bores had been drilled into the Basin providing artesian flows. This had increased to more than 3000 by the end of the 1950s (Cox and Barron, 1998).


**Figure 2:** Great Artesian Basin

## 2. THE GAB AND THE PASTORAL INDUSTRY

For more than a century the pastoral industry in the Basin has relied on access to artesian water from the GAB and developed management practices that rely on delivering water to stock through open drains. However, the volume of water which flows from the hundreds of uncontrolled GAB bores into bore drains far exceeds that required by stock and causes a number of land-use problems. Figure 1 shows the current water use from the GAB. The pastoral industry currently uses about 500 000 ML of GAB water annually. Many pastoralists have already installed closed water delivery systems and are using water much more efficiently. However, once the remaining artesian bores are controlled and the open bore drains replaced with closed piped systems, it is estimated that about 350 000 ML will be saved each year while still supplying the needs of the current industry. Approximately 90% of water that flows into open bore drain systems is wasted through evaporation and soakage (Cox and Barron, 1998). The practice of using bore drains to transport water and the necessity to take much more water than is required as a result of this practice has over time resulted in loss of pressure in the aquifer.

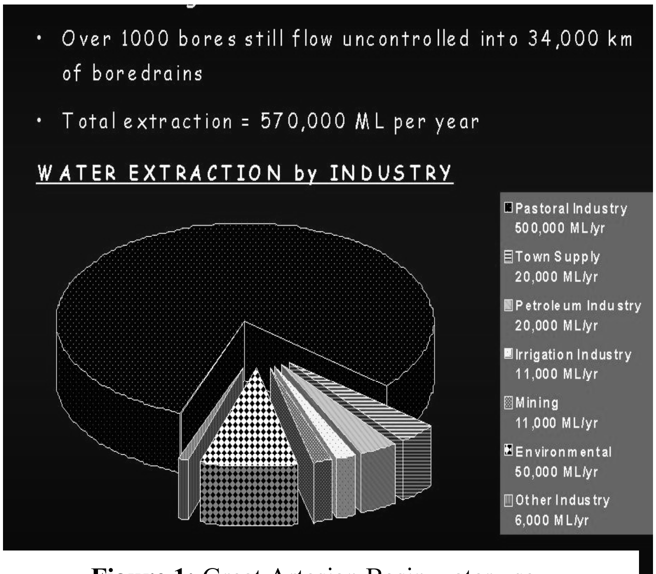


**Figure 1:** Great Artesian Basin water use

This problem was recognised more than eighty years ago and since that time attempts have sporadically been made to reduce waste and manage GAB water better. The map in figure 2 shows that the GAB underlies parts of the states of Queensland, New South Wales, South Australia and the Northern Territory. Even though the GAB is a continuous aquifer, each of the State jurisdictions has taken a different approach to managing the rights and responsibilities of those who use GAB water (Seccombe, Russell, and Brake, 1998).

Legislation for the management of the GAB was passed in Queensland in 1910 and in New South Wales in 1912. Around the turn of the 19th Century, South Australian Pastoral Legislation proclaimed travelling stock routes and made provision for surveyed water conservancy areas around bores for the watering of travelling stock and the convenience of travellers on pastoral leases in the GAB. Lines of bores were drilled by the Government along these stock routes at about two days distance for travelling mobs at either line of sight or shortest walking distance. Probably the most famous travelling stock route was the Birdsville to Marree route that is still referred to as the Birdsville Track (Yelland, 1998).

Concern for diminishing flows led to five interstate conferences on the Artesian Water of the GAB between 1912 and 1928. In October of 1914 the Chairman of the Interstate Conference on Artesian Water, Mr. EF Pittman, stated in his report to the Queensland Premier:

*— insomuch as the artesian supply is a national asset, every member of the community has an interest in its (the GAB) conservation. We venture to urge, therefore, that no person should be allowed to put down a bore unless he be prepared to observe the precautions necessary to minimise waste or leakage.*
(Report of the Second Interstate Conference on Artesian Water, Brisbane, 1914).

The 1939 Interstate Conference commissioned a report from the Artesian Waters Investigations Committee on the structure of the Basin and the issue of falling pressures. This report was completed in 1945 but it was not until 1954 that each of the State jurisdictions agreed to address the recommendations of the report. During the next three decades, each of the jurisdictions made some gains through licensing regulation and investments in bore rehabilitation. In 1977, the South Australian Government began a bore rehabilitation and control program. An interstate technical working group was formed in 1987 to fill some of the knowledge gaps about the physiography of the Basin. This working group later took on an *ad hoc* policy advisory role for governments with Basin jurisdiction.

During the 1980s Basin-wide concern continued to grow amongst all interest groups including users and governments. Even with the gains that were made in the first three-quarters of this Century, it became obvious that institutional arrangements in the separate jurisdictions of the Basin were unable to stem the unacceptable impacts being caused by the loss of artesian pressure and the waste of Basin water. By the mid 1990s over 3000 bores continued to flow freely into more than 34 000 km of boredrains. As a result, approximately 1/3 of the original artesian bores had ceased to flow and over 1 000 natural springs along with their water dependent ecosystems have been lost (Seccombe, Russell, and Brake, 1998).

## 3. MANAGING THE GAB FOR THE FUTURE

Historically, a poor understanding of the GAB and inadequacies in the technology of the times often limited the effectiveness of management decisions. The current problem, however, is not just the result of poor knowledge and technology. The size and remoteness of the Basin and the wide distribution of the bores has meant that governments and users have failed to grasp the economic, environmental and cultural significance of the GAB and acknowledge the unacceptable consequences of current management practices.

For almost a century, water users, decision-makers and opinion leaders have grossly undervalued the Basin and allowed the continuing accumulation of an unsustainable natural debt that threatens to severely limit many of the Basin's values. This unwillingness to acknowledge the true costs and benefits that flow from the use of the water resource has not engendered the will or urgency among politicians or water managers to undertake the institutional reform or strategic investment necessary to adequately address long-standing management problems.

The Great Artesian Basin underlies four separate jurisdictions, each with separate natural resource management policies, legislation and practices. The recharge and natural discharge areas are concentrated on the eastern and western margins of the Basin, while the major extraction areas are towards the centre of the Basin. However the aquifer system is in many respects a single entity and the effects of use and management in one State may be reflected in pressures and water availability in another. In addition, the Commonwealth also has an interest in improving the management of this nationally and internationally important natural asset and in sustaining the community benefits that are supported by the use of the GAB's water. Consequently the management of the Basin remained unacceptable and fragmented while the demand for water increased.

By the mid-1990s no person or group had been able to mobilise sufficient resources and coordinated effort to achieve the Basin-wide changes required in infrastructure renewal and management practices. This is despite a much improved knowledge of water management technologies and the benefits that could accrue once the Basin is well managed. There was no single point of reference for policy development or programs capable of dealing with cross-jurisdictional issues.

Individual jurisdictions have made efforts to address these issues. South Australia has made a concerted effort in rehabilitating the Government owned bores since 1978 and Queensland rehabilitated over 300 bores in a period beginning in the late 1980s. In addition much effort has been made in research and management of the mound springs in South Australia since the 1970s. However these programs have not been coordinated across the basin and therefore potential benefits have been lost.

A workshop organised in 1995 by Mr John Seccombe, a pastoralist from Queensland and driven by concerned GAB stakeholders suggested that a Basin-wide coordinating group should be formed. As a result industry groups and governments cooperatively formed the Great Artesian Basin Consultative Council in 1997. Subsequently, community-based advisory committees were involved in each of the State jurisdictions. This was the first real attempt at institutional reform to engender strategic Basin-wide cooperation and investment.

Since its formation, the Council has worked to raise the profile of the GAB and the need for improved management. The Council has produced a Resource

Study that presents an information base for decision making and a Strategic Management Plan (SMP) that presents a comprehensive framework to achieve sustainable management of the Basin over a fifteen-year period.

For the first time in the history of GAB management, there is a process for negotiating natural resource management outcomes between jurisdictions on behalf of all GAB stakeholders and in the best interests of the resource. Issues such as water rights and allocations, water usage, water markets, capital investments in infrastructure, preservation of environmentally sensitive areas and areas of cultural and social importance are all issues of cross-jurisdictional interests and importance. We now have a much better understanding of the capacity of the GAB, the technology to control bores and an SMP providing a framework for the judicious management of the water supply. We know that a well managed GAB has the capacity to supply current users and support additional development or shifts to higher value industries without causing unacceptable impacts on cultural or environmental values. However, turning this understanding into appropriate on-ground change still proves problematic (Seccombe, Russell and Brake, 1998).

## 4. IMPLEMENTATION OF THE STRATEGIC MANAGEMENT PLAN

The SMP is based on the premise that water users, Governments and other stakeholders all have important roles to play in infrastructure renewal and the management of the Basin. It suggests that an appropriate mix of capacity building, incentives and regulation will be required to achieve the objectives of the SMP and that this will need to be varied to meet regional needs within the Basin. Community-based committees within each of the State Jurisdictions are expected to work in partnership with Government agencies and water users to produce plans and develop programs to implement the strategies proposed in the Basin-wide Strategic plan.

The SMP emphasises the need to change the ‘hearts and minds’ of public officials and administrators as well as water users. All interest groups including water users and governments must acknowledge that they share in the responsibility for the current problem and make a meaningful contribution to the solution.

The SMP recognises that most of the responsibility for sustainable Basin management rests with water users. However, State and Commonwealth Governments and other stakeholders have key roles in reforming current management practices. State governments have a constitutional responsibility to protect natural and cultural heritage values and to ensure water is used judiciously to support community values and benefits. Governments may also share in investments when market or regulatory frameworks fail and where current investment is insufficient to achieve best outcomes. Governments also need to participate where a public good or benefit can be shown (Great Artesian Basin Consultative Council, 2000).

The Strategic Management Plan has provided the trigger for a significant investment of public funds by the Commonwealth and the States in a cost sharing arrangement with the private sector. This investment, apparently secure for the first five years of the planned fifteen year period required to address the problems of the GAB, has been a positive step in integrating efforts across the basin. It remains to be seen whether the commitment to maintain the impetus is really there.

## 5. BLOCKAGES TO IMPLEMENTATION

Government and its Ministers in three States, the Northern Territory and the Commonwealth all have some role in the management and the provision of funding for the management of the GAB. Aspects of Basin management and investment fall within State and Commonwealth legislation in each jurisdiction and the implementation of the Acts is assigned to appropriate State or Commonwealth government departments. When the Legislation and government agencies responsible for industries and resources that are dependent on GAB water are added, the number of State and Commonwealth ministerial portfolios and government departments that share in decision making concerning integrated resource management in the Basin makes the notion of coordination and integration quite problematic.

The development of the Strategic Management Plan for the GAB and the agreement for the Sustainability Initiative to fund the first five years of one of the key objectives took more than three years to complete. It would never have been completed without the cooperation and active support from a number of State and Commonwealth Ministers, government departments and industry groups. People living in the Basin and other interest groups have generally accepted the need for change and seem willing to negotiate with State Committees. The important developmental as well as the instrumental dimension of the planning process needs to be recognised (Considine, 1994). The planning process resulted in a much better understanding and cooperation amongst interest groups as well as a Strategic Management Plan, but most of the work to achieve the desired outcomes in the GAB still lies ahead. The planning experience did suggest, however, that there are a number of blockages that still need to be dealt with.

## 6. POLITICAL AGENDAS

Problems will arise as the Council attempts to maintain the governments’ focus on the Basin past the next State and Commonwealth elections, especially if there is a change in government or other priorities arise that seem to be of greater importance to the community. Much of the time and effort of those involved in implementing the SMP will be required to maintain the focus of the community on the GAB and try to keep it on the agenda of those who make decisions concerning resource allocation.

There is evidence that change in government need not result in the termination of programs, the bore rehabilitation program in South Australia is one example of an initiative that has transcended elections an changes of Government over an extended period.

Single bottom line
Pastoralists who operate their businesses with a very large overdraft and an inadequate cash flow often find it difficult to seriously consider partnerships, shared investments or changes in management practices that do not have immediate economic benefits. Often returns begin to accrue from more judicious use of the GAB only after an additional investment of resources and a substantial time lag. Unless on-ground changes can be made in a way that has positive short as well as long-term business outcomes, landholders whose financial position makes it imperative that they focus on a single bottom line will continue to be very reluctant to participate.

Portfolio Imperatives
Facilitating communications and the sharing of resources between agencies within the same government has proved extremely difficult. Achieving substantial cooperation between governments is even more difficult. The most difficult stumbling block may well be trying to sustain inter-agency and intra-government cooperation and commitment over fifteen years as people, priorities and institutional arrangements change with funding, election and restructuring cycles.

Loss of Civil Society
People's willingness to contribute to the common good without thought of personal gain has always been one of the key tenets of outback culture. Economic pressures and traditional community structures are changing in Pastoral areas. Western societies' emphasis on individual rights and economic outcomes is undermining civil society; the idea that '*each of us is better off, if all of us are better off*' is no longer a key tenet that drives much of society (Holmes and Sunstein, 1999). Individual rights are often very expensive and personal agendas that compromise the common good make it difficult to focus on sustaining long-term community benefits.

Poor Information
Funding cycles that focus on Strategic Planning and consultation processes some times identify strategic knowledge gaps but seldom provide sufficient resources to fill them once they are identified in plans. Money for research, monitoring and evaluation are not often seen as germane to achieving sustainable outcomes. Part of the problem may be the inability of the scientific community to undertake strategic research, and deliver information in a form that is useful to opinion leaders and decision makers. Unwillingness to invest in filling information gaps and creating informed working environments for partnerships can severely curtail resource outcomes.

Fear, Suspicion, and Lack of Trust
The GAB is very large and remote. Those who need to be involved in capacity building and decision making come from a wide range of bureaucratic, industrial and local ideological backgrounds. People who try to run personal agendas by reinforcing long-held stereotypes and spreading misinformation can easily fuel fear, suspicion and lack of trust (Brake 2000).

## 7. CONCLUSION

The GAB presents a very good case study in regional resource management. The resource has been well researched, the major management issues are relatively straightforward and have been recognised for almost a century. Our current understanding of the Basin, the new technology for bore control and water delivery and the institutional arrangements now in place provide the best opportunity that has ever existed to manage the Basin sustainably for the benefit of this and future generations. The challenge is to reconcile the issues, understanding and expectations that drive current management practices in the pastoral industry with the bureaucratic issues, understanding and expectations that drive various State and Commonwealth Departments.

It is plausible to suggest that the greatest threat to achieving the sustainable management of the Basin may come from governments' unwillingness to undertake appropriate institutional reform rather than from pastoralists' unwillingness to reform their management practices. Those who build careers by restructuring institutions and redesigning processes seem to lose sight of the need to support long-term change as they try to make their mark during the politically-driven restructuring and refocussing that inevitably follows elections or the appointment of new Ministers or Departmental CEOs. It will be very interesting to see if community leaders and decision makers have the will to work cooperatively and remain focused long enough to ensure that the partnerships and shared investments really work and achieve the on-ground changes required over the next fifteen years.

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# Climate change

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**Summary**
The earth's atmosphere is undergoing increases in greenhouse gas concentrations that have not been experienced for hundreds of thousand of years. To assess the impact of these changes on the earth's climate, the World Meteorological Organisation and the United Nations Environment Programme established the Intergovernmental Panel on Climate Change in 1988. Its task was to prepare authoritative assessments in order to advise governments and the broader community of the current state of science and whether or not there were well grounded concerns for the future of the earth's climate. The most recent report concluded *"most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations"*. They also projected significant changes in the earth's climate. Whilst actions to reduce net emissions may limit the magnitude and the rate of change, some adaptation will be required. Determining the timing and the regional impact of change requires further observation and improved simulation of the climate system. In parallel with these developments, appropriate adaptation and response strategies across a broad spectrum of sectors need to be developed.

## 1. INTRODUCTION

By the 1980s, it was clear that greenhouse gas concentrations in the atmosphere, particularly carbon dioxide, had increased substantially during the 20th century. Global averaged temperatures had also increased but a definitive link between the temperature increases and greenhouse gas concentrations had not been established. To address the growing concern that human activities were changing the composition of the atmosphere and that there could be far reaching impacts on the climate of the earth, the World Meteorological Organisation (WMO) and the United Nations (UN) Environment Programme established the Intergovernmental Panel on Climate Change (IPCC) in 1988. Its task was to prepare authoritative assessments in order to advise governments and the broader community of the current state of science and whether or not there were well grounded concerns for the future of the earth's climate.

The IPCC was tasked with producing credible scientific assessments of the information available in the peer reviewed literature, to distil this information and present it in an intelligible fashion to policy makers and the broader community. The IPCC process was not a research program but rather an assessment process. To ensure the confidence of governments in the assessments, the IPCC was established as a formal intergovernmental body under the control of the member governments of the WMO and the UN. The role of governments was *not* to decide on scientific issues but rather to ensure that the views of the entire scientific community were considered and assessed in a rigorous and balanced way.

The IPCC process and the assessments quickly became a major focus of attention in the lead up to the 1992 Rio Earth Summit. Professor Bert Bolin was the first chair of IPCC and the First Assessment Report (FAR) consisted of three volumes focusing on the underlying climate science, impacts and response strategies. An update was produced in 1992 as input to the final stages of negotiation of the United Nations' Framework Convention on Climate Change. The Second Assessment Report (SAR) was completed in 1995 and again consisted of three volumes focussing on the science, impacts and responses, and crosscutting economic and social dimensions. The IPCC also produced a series of Technical Reports and Special Reports.

Dr Robert Watson (with experience with NASA, the White House Office of Science and Technology and the World Bank) replaced Professor Bolin as chair of IPCC for the Third Assessment Report (TAR). A set of potential lead authors was selected from the 3000 nominations and a scoping meeting for the TAR held in July 1998. This led to the identification of additional lead authors and the appointment of convening lead authors for each of the chapters of the three reports (focussed on science [IPCC, 2001], impacts and adaptation, and mitigation). The lead authors were responsible for soliciting contributions from the wider community and drafting the individual chapters. Each chapter then went through an informal scientific review, a formal scientific (expert) review, a formal government and scientific review before final comments by governments. Two review editors were appointed for each chapter to ensure that all of the comments from the scientific and government review processes were addressed seriously. This resulted in extensive rewriting of the original draft chapters and the formulation of a formal written response to each and every comment received. For Working Group 1 there were 122 lead authors, 515 contributing authors, 21 review editors and 420 expert reviewers.

In addition to the individual chapters, a Summary for Policy Makers (SPM; IPCC, 2001) and a Technical Summary for each of the three working groups was prepared and reviewed. The 18 page SPM of Working Group 1 was finally adopted by the 99 national delegations who attended the Eight Session of Working Group 1 in Shanghai in January 2001. This required consideration of the 100 pages of consolidated comments and working through the SPM line by line to ensure scientific accuracy and the maximum clarity possible. The underlying chapters were also accepted at Shanghai. Many of the results reported here come directly from the SPM.

## 2. CHANGING GREENHOUSE GAS CONCENTRATIONS AND RADIATIVE FORCING

Changes in climate can occur as a result of internal variability of the climate system or as a result of natural or anthropogenic forcing. Natural forcing can result from, for example, solar variability or volcanic activity. Present concern focuses on the major anthropogenic forcing resulting from changes in greenhouse gas concentrations in the atmosphere.

After water vapour, the principal greenhouse gas is carbon dioxide. Its concentration has increased by about 31%, from about 280 ppm prior to 1750 to today's value of greater than 360 ppm. This value has not been exceeded during the past 420 thousand years, and probably not during the last 20 million years. Three quarters of the increase since 1750 comes from the burning of fossil fuels and the remainder is predominantly from land use changes, especially deforestation. There have also been significant increases in methane, nitrous oxide and halocarbon concentrations. These increases in the well-mixed gas concentrations result in a positive radiative forcing of about 2.4 W $m^{-2}$ that tends to warm the planet. In addition, changes in ozone concentrations in the stratosphere and the troposphere tend to cool and warm the planet respectively.

Anthropogenic aerosols, primarily from fossil fuel and biomass burning, are relatively short lived and mostly produce a negative (cooling) radiative forcing. There is lower confidence in the understanding of the direct and the indirect (through their effects on clouds) radiative forcing from aerosols than for the well-mixed gases.

Over the past century natural forcing factors (solar and volcanic) have been small. Their combined radiative forcing for the past 20 years, and possibly the past 40 years has been negative.

## 3. CHANGES IN 20^TH^ CENTURY CLIMATE

Global average surface temperature (the average of near surface temperature over land and sea surface temperature) has increased since 1861 by 0.6ºC (Figure 1a). The data indicate that the 1990s was the warmest decade in the instrumental record and 1998 the warmest year. There is considerable decadal variability with the warming concentrated in two periods, between 1910 and 1945 and after 1976.

Temperature increases have tended to be larger at night and over the land (compared with the ocean).

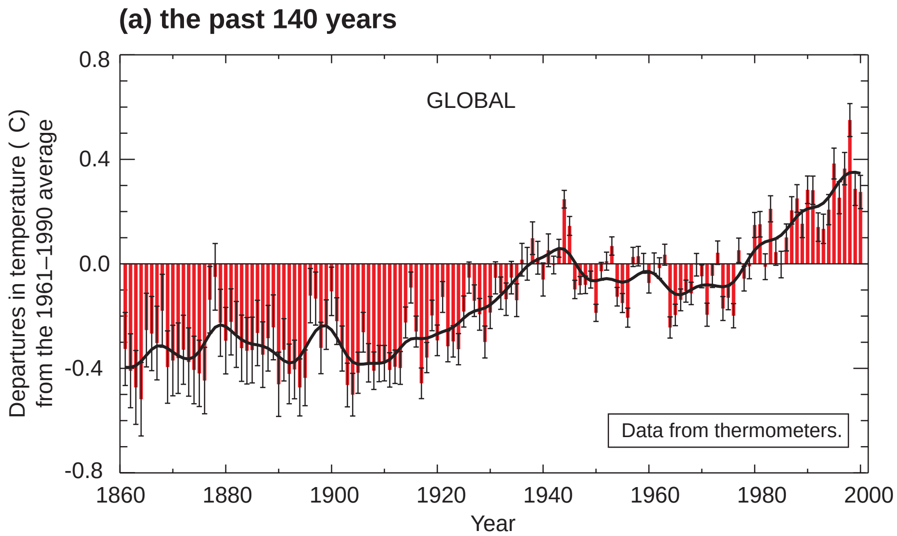
Proxy temperature data (tree rings, corals, ice cores, historical records; Figure 1b) indicate a slight cooling between 1000 and 1850. It is likely that the 20$^{th}$ century increase in temperature is likely to be the largest in any century for the last millennium. It is also likely that, as for the global data, for the northern hemisphere the 1990s was the warmest decade and 1998 the warmest year (Figure 1b).

A significant point of controversy and continuing investigation is the warming of the lower troposphere. Since the 1950s, balloon data indicate the lower 8 km of the atmosphere has warmed by 0.1ºC/decade. Since the start of the satellite record in 1979, both balloon and satellite data indicate a rate of warming of 0.05ºC/decade compared with the surface rate of warming of 0.15ºC/decade. The differences are significant and the largest differences occur over the tropical and subtropical regions. The reasons for the difference are poorly understood.

Changes in other aspects of the climate system have also been observed (with varying degrees of confidence). These include a decrease in snow and ice cover, a global average sea-level rise (see section 6), an increase in ocean heat content, precipitation increases in mid to high latitude land regions of the northern hemisphere and over tropical (10ºS to 10ºN) land regions and a decrease over much of the northern hemisphere subtropical land areas. Some aspects of the climate system appear not to have changed; for example no significant trends in Antarctic sea ice extent have been detected.

## 4. HUMAN INFLUENCE ON THE CLIMATE SYSTEM

The ability to detect the impact of changing concentration of greenhouse gases on the climate system requires a good observational data base and an ability to model the climate system. Over the last decade or so there has been a dramatic improvement in the ability of models to simulate observed climate. Present day state-of-the-art climate models include components simulating the atmosphere, the land surface, the oceans and sea ice, sulphate and non-sulphate aerosols and the carbon cycle. Examples of progress include an improved ability to simulate atmospheric water vapour, ocean heat transport, sea-ice dynamics and aspects of climate variability such as El Niño-Southern Oscillation and the North Atlantic Oscillation. As a result, some of the most recent models produce satisfactory simulations of the climate system without the need for unrealistic adjustment of heat and water fluxes at the air/sea interface. However, these models cannot yet simulate all aspects of observed climate and continuing refinement is required for more useful predictions of the timing and regional impact of climate change.



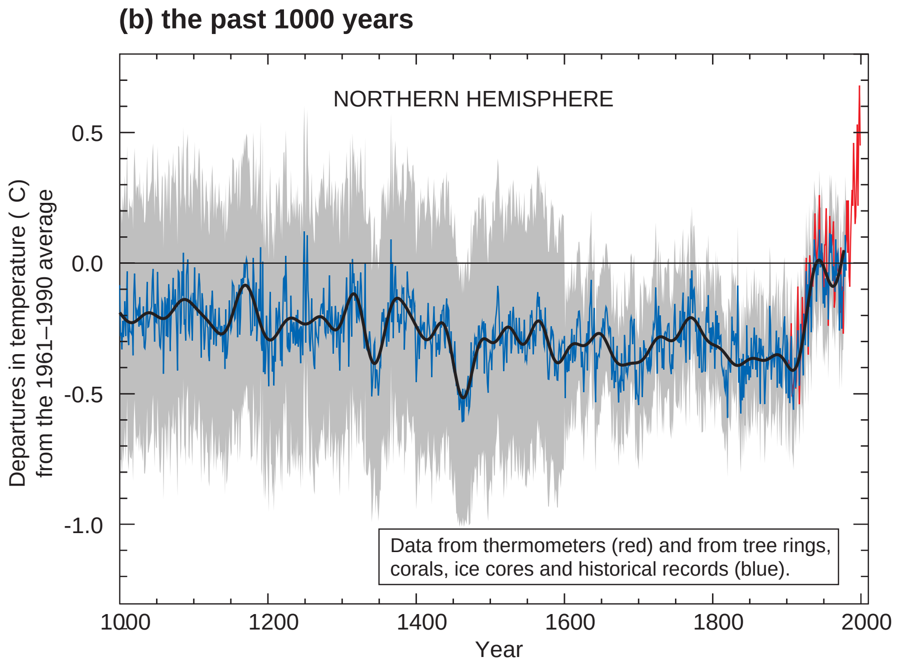




**Figure 1:** Variation of the earth's surface temperature. (a) Departures of the global average surface temperature relative to the average over the period 1861 to 1990. The whiskers on the annual averages are the 95% confidence limits. (b) Average northern hemisphere surface temperature data over the past 1000 years from proxy data. The grey region is the 95% confidence range. (From IPCC, 2001.)

Since the SAR, improved models, a longer and more carefully scrutinised climate record and reconstruction of climate data over the last millenium have led to the conclusion that the observed warming during the 20$^{th}$ century is unlikely to be the result of natural variability alone. New model estimates of the response of the climate system to greenhouse gas forcing and improved statistical tests (including comparisons of the observed and modeled pattern of warming) have found evidence of anthropogenic forcing of the climate system over the last 35 to 50 years. Natural forcing does not explain the observed warming over the second half of the 20$^{th}$ century although it may have contributed to the warming in the first half of the 20$^{th}$ century. The best agreement between the simulated and observed temperature record occurs when all forcings (natural and anthropogenic) of the climate system are included in the models.

As a result of these (and other findings), the IPCC (2001) concluded, *"In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations."*

Both observations and models indicate it is very likely that 20$^{th}$ century warming has contributed significantly to sea-level rise through ocean thermal expansion and the melting of glaciers.

## 5. PROJECTIONS FOR THE FUTURE

Projections of climate change are based on a set of emission scenarios (Figure 2a) for the various greenhouse gases and aerosols from the IPCC Special Report on Emission Scenarios (SRES; IPCC, 2000). These emission scenarios are based on a range of plausible scenarios regarding demographic change, social and economic development and the rate and direction of technological change. All scenarios represent futures that are generally more affluent than today. For comparison purposes, projections were also done with the IS92a emission scenario used in the Second Assessment Report. The IS92a carbon dioxide emissions lie in the middle of the range of the SRES scenarios. All of the SRES scenarios have substantially lower sulphur dioxide emissions in 2100 compared with the IS92a scenario.

Carbon cycle models project that the large range in the SRES emission scenarios results in atmospheric $CO_2$ levels in 2100 of between 540 and 970 ppm (compared with the pre-industrial levels of 280 ppm; Figure 2b). While other greenhouse gas levels also increase, the fraction of the net anthropogenic radiative forcing from $CO_2$ increases from slightly more than half to about three quarters by 2100.

Projections of globally averaged temperature increases range from 1.4ºC to 5.8ºC over the period 1990 to 2100 (Figure 2d), with greater warming over the land than the oceans. Temperature projections at the upper end of the range are larger than in the SAR primarily as a result of lower projected sulphur dioxide emissions in the SRES scenarios. The projected rate of warming is much larger than the observed change during the 20$^{th}$ century and is very likely to be without precedent in the last 10 000 years.

Global average precipitation is projected to increase, particularly over northern mid- to high latitudes and Antarctica in winter. At low latitudes, precipitation projections include both regional increases and decreases.

## 6. PAST AND FUTURE SEA-LEVEL CHANGE

Sea-level rise from climate change potentially has major impacts on coastal regions and hence has been one of the areas of focus of the IPCC reports (Church et al., 2001). Since the last glacial maximum, global averaged sea level has increased by more than 120 m as major northern hemisphere ice sheets have melted. Much of this melting was complete by six thousand years ago and rates of sea-level rise over the last three thousand years (up to the 19$^{th}$ century) were of order 0.1 to 0.2 mm yr$^{-1}$. During the 20$^{th}$ century, tide gauge observations indicate sea level has risen at the rate of 1 to 2 mm yr$^{-1}$, faster than the rate during the 19$^{th}$ century. No increase in the rate of sea-level rise has been detected during the 20$^{th}$ century.

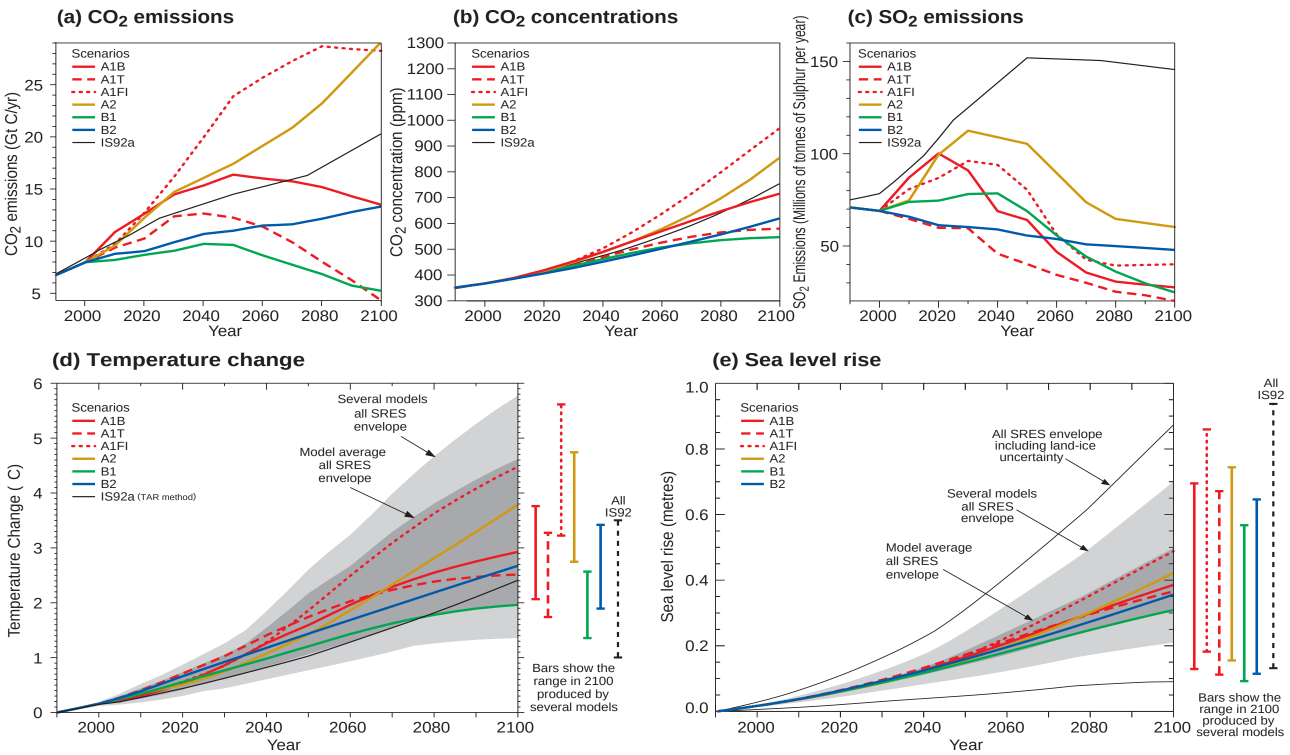



**Figure 2:** Projections for the 21$^{st}$ century. (a) Carbon dioxide emissions for the six illustrative SRES scenarios and the IS92a scenario from the SAR. (b) Projected atmospheric carbon dioxide concentrations. (c) Sulphur dioxide emissions. (d) and (e) Projected temperatures and sea level. (From IPCC, 2001.)

Ocean thermal expansion (principally from warming the upper kilometre of the ocean) and the melting of non-polar glaciers are significant components of the 20th century rise. In addition there is thought to be a contribution from melting of the Greenland ice sheet, an offsetting contribution from increased precipitation over Antarctica and a contribution from ongoing adjustment of the Antarctic and Greenland ice sheets since the end of the last glacial maximum.

The area of greatest uncertainty at present is the storage of water on land. The two major papers in this area, Gornitz et al. (1997) and Sahagian (2000), arrive at somewhat different conclusions. Terrestrial contributions come from ground water mining, increased storage in lakes and reservoirs, infiltration into aquifers from reservoirs and irrigation and changes in runoff from urbanisation. Urgent attention is required for improved estimates of the terrestrial storage term so that the 20th century global water budget can be more satisfactorily closed.

For the period 1990 to 2100, sea-level rise as a result of climate change is projected to be between 0.09 and 0.88 m (Figure 2e), with the largest contributions coming from ocean thermal expansion and melting of non-polar glaciers and a smaller contribution from the Greenland ice sheet. For Antarctica, current temperatures are so cold that the projected warming for the 21st century will not result in significant melting. However, increased precipitation is expected. Current models of the West Antarctic Ice Sheet (which is grounded below sea level) indicate that it is unlikely to make a significant contribution to sea level in the 21st century but its dynamics are inadequately understood, especially for projections on a longer time scale.

Ocean thermal expansion and rising sea levels will continue long after greenhouse gas concentrations are stabilised. For a sustained warming above 3ºC, the Greenland ice sheet is projected to melt, leading to a sea-level rise of up to 7 m over millennia. For a warming of 5.5°C over Greenland, the projection is for a rise of sea level of over 1 m by 2500 from melting of the Greenland ice sheet alone. (Note that for a range of models, projected temperature increases over Greenland are a factor of 1.2 to 3.1 greater than the global average.) Current ice dynamic models suggest that the West Antarctic Ice Sheet could contribute up to 3 m over 1000 years, but these results are strongly dependent on model assumptions.

## 7. CONCLUSIONS

The earth's atmosphere is undergoing unprecedented changes that have not been experienced for hundreds of thousands of years. These changes are expected to lead to significant changes in the earth's climate. Whilst actions to reduce net emissions will limit the magnitude and the rate of change, some adaptation will be required. Determining the timing and the regional impact of change requires further observation and improved simulation of the climate system. In parallel with these developments, appropriate adaptation and response strategies across a broad spectrum of sectors need to be developed.

## 8. ACKNOWLEDGMENTS

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# The River Murray and writing the Constitution

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**Summary**
Concern about the future development of the River Murray was a major factor driving the demand for federation in the 1890s. Although it was discussed for longer than any other single issue at the 1897/98 constitutional convention no agreement was reached about how it should be managed. The main product of the debate was section 100 of the constitution which provided for 'reasonable use' of the waters of rivers for conservation and irrigation. After it was incorporated in the draft document, the New South Wales delegates tried and failed to have it removed. The South Australians said their State was now worse off than before the convention. Alfred Deakin later described section 100 as the most complex and obscure section of the constitution. What did the three States with an interest in the Murray want when they came together to discuss federation? Why was it so difficult to agree on this issue when so many others were resolved successfully? Section 100 remains in the constitution and could one day be the subject of action in the High Court. So what did the members of the convention think they were accepting when they finally agreed to it?

## 1. INTRODUCTION

Australian colonial politicians were aggressive economic developers. Control and development of water resources was a high priority. For the representatives from New South Wales, Victoria and South Australia, coming to the 1897/98 convention to draft the future Australian constitution, control of the waters of the River Murray catchment was one of the most important issues to be discussed.

In the weeks leading up to the first session in Adelaide, Sir Richard Chaffey Baker, President of the South Australian Legislative Council, circulated a statement to newspapers throughout the State putting forward the arguments for and against Federation. With regard to the Murray he wrote:

> *The question concerning the water of the River Murray which arose between New South Wales and South Australia some time ago has never been settled and is bound to arise again in more aggravated form as more and more water is used for irrigation on the headwaters of the River Murray and its tributaries. In the absence of Federation there is no authority to settle this or any similar question and both it and the ever recurring dispute between South Australia and Victoria are examples of questions which rise to friction and dispute and sometimes ultimately end in animosity and war.* (The Advertiser 2/3/1897).

Development of the Murray system was also an important issue for New South Wales. Writing of his preparations for the convention, the premier, George Reid, later explained that he placed a high priority on the need to protect his States' unfettered access to the water of rivers within its borders because

> *schemes of intensive culture for which the river waters were necessary were the only chance we had of making our remote interior a hive of human industry.* (Reid 1917 p136).

Speaking for Victoria, Alfred Deakin's views about the value of the Murray had been public knowledge for years:

> *If Victoria is to continue to progress in the settlement of her people upon the lands and the multiplication of her resources by the conquest of those lands hitherto regarded as worthless, if she is to utilise her abundant natural advantages, bring her productiveness to the highest point, and secure to the agricultural population of her arid districts a permanent prosperity, it must be by means of irrigation.* (La Nauze 1965 pp85/86).

## 2. PROSPECT OF FEDERATION

Before federation New South Wales and Victoria saw the benefits of cooperation between themselves but did not concede that there was significant role for the proposed national government to play. In contrast, for South Australia it was crucial that this issue be brought within the national jurisdiction. Experience had shown that when they negotiated direct they had little or no influence over New South Wales and Victoria on this issue. However in a federated national system there was the potential to form alliances with the other three States that could be used against its two up-river rivals.

The river trade was in decline by the 1890s and many historians have written of this period confident of its eventual demise. However that was not the dominant perception in South Australia at the time. Instead they looked to a regulated river system which, rejuvenated by national investment in a network of locks and upper catchment storages to provide navigable flows during summer, would transform the Murray and its tributaries into the Mississippi of south-eastern Australia.

In considering the 1890s disputes over the Murray, it is possible to be misled by the relatively small volumes of water that would have been diverted by the schemes being considered at the time. The constitutional convention was meeting during a period when the catchment of the Murray had been in severe drought for a number of years. This would have increased awareness among the delegates, of the importance of its water for the inland regions. Although proposals for major storages were being discussed, the extractions of the 1890s and 1900s were occurring many years before the major dams on the Murray system were built. For any proposals to be implemented in the short to medium term the water would need to be taken out of the rivers in the summer and autumn, the time of maximum demand for irrigation. At that time of year water levels in the Murray were usually very low. Even before significant levels of irrigation began, navigation was often difficult or impossible during this season. Consequently, the extraction of even small volumes of water for irrigation by the up-river States would have significantly lengthened the period of time for which the river was impassable for river boats. In addition, extended periods of low flow also allowed saline groundwater to flow back into the river along the exposed banks. In some summers water in the South Australian reaches was too saline to drink or use for irrigation, a major impediment to development along the river. For example, not many years after federation, in the drought year of 1914/15 salinity levels at Morgan reached 10 000 EC. (800 EC is the maximum level now recommended as 'desirable' by the World Health Organisation. Water is undrinkable for humans beyond about 2 500 EC.)

## 3. THE CONSTITUTIONAL CONVENTION

After a long hiatus following the first serious attempt to federate in 1891, the process of federation had resumed in March 1897 with the opening session of the Australasian Federal convention in Adelaide. Made up of directly elected delegates from most of the six colonies, it met for about a month in Adelaide, three weeks in Sydney and two months in Melbourne where it finished in March of 1898. The draft constitution was then put to the vote in each colony and after various adventures, passed into law by the British Parliament on July 9th 1900.

During the three sessions of the convention, control of the River Murray was debated for longer than any other issue. The 'rivers' debate involved three distinct but inter-dependent issues; water for irrigation and stock, the protection and enhancement of navigation activities and the relationship of both issues to the management of the rail networks of the three states. It was the complexity of these interrelationships and the perception that they involved fundamental State interests and rights, which caused the debate to become so heated, long and incomprehensible to the other non-involved states.

Discussing the Melbourne session of the convention the constitutional historian J.A. La Nauze, commented that if the two issues, 'the rivers' and the powers of the upper house, had not been settled, *there could have been no constitution and no Federation*. The rivers issue was publicly debated for a week, moved to a private conference, then brought back once again to the public session for another week in February. La Nauze described the debate as more an endurance test than an exercise in clarification. According to La Nauze the up-river States wanted to protect their right to use the Murray River system for irrigation and the South Australians wanted to prevent them from diverting so much water that it would threaten navigation.

There is no disputing that, at least in the short term, the main issue for the South Australian delegation was the protection and enhancement of their state's Murray based navigation system. However, John Hannah Gordon, leader for the South Australians in the rivers debate, did state that ultimately, irrigation was the more important. While energetically putting the case for navigation, he told the delegates that river transportation could if necessary, be replaced by alternative transportation systems such as rail, but that there was no substitute for water when it came to food production. He spoke passionately in favour of the principle that the new national government should have responsibility for both navigation and irrigation. He argued that they should be managed in a coordinated way in order to balance the two needs (Official RecordVol.1p36).

Reflecting a view of water rights that had long been established in English riparian law, Gordon asserted that water was similar to sunlight, which all people had the right to share in common. He told the delegates that George Reid was effectively saying that because the sun shone on New South Wales, *it was New South Wales' sun.* A later interchange reveals the same divide:

> *Barton (New South Wales ) What is the difference between taking away some of our water and taking away some of our land?*
> *Deakin (Victoria) Exactly.*
> *Kingston (South Australia) But it is not your water.* (Official Record Vol.1 p44*).*

As described by La Nauze the debate was conducted in terms that were appropriately serious and dignified. However, *The Advertiser*'s correspondent presented the discussion in a more lively fashion which suggests that La Nauze's sober account glossed over strong tensions. Quoting an interchange between Josiah Symon for South Australia and George Reid for New South Wales, *The Advertiser* reported

> *Symon: 'In the nature of all that is federal surely this is a matter for such control'.*
> *'Why not in this matter' interjected Mr Reid 'throw yourselves on our charity and we will treat you as we have always done - most handsomely!'*
>
> *Even South Australians when they thought of the correspondence pigeon holed, of requests for a conference refused, of suggested settlements disregarded, could not repress a smile at so subtle a joke.* (Advertiser 25/1/1898).

The intensity of the debate comes through the record. Gordon dismissed New South Wales' argument for ownership of the water in its main rivers as *the rustic cackle of their bourg*. Reid described the South Australian case as *the ablest set of arguments upon a bad point that I have ever heard,* claiming that Gordon's skills were such that he could argue his way into heaven. Gordon replied that Reid's arguments would need to be more honest *if he wishes to enter heaven*. Years later, Alfred Deakin in describing Reid's performance during this debate, quoted a description of the Irish politician Daniel O'Connell which he thought applicable:

> *His coarseness, violence and cunning were seen to the worst advantage ....the most daring perversions of truth and justice were driven home by appeals to the emotions.* (Deakin 1944 p87).

The tensions between river transportation and the growing rail networks spreading out from Sydney and Melbourne, were complex. All three States were competing for the business of the Riverina. Gordon argued that freight rates should not be used as a tool for conflict and looked to the proposed national system for some process that would ensure fair competition. Deakin was concerned with similar issues. (Official RecordVol.1p40) Use of freight rates to undercut competition was not a subtle business. Evidence presented to the 1902 joint inter-state royal commission on the River Murray later revealed that Victoria offered customers in the New South Wales Riverina, freight rates for goods loaded at Echuca that were about one third of the rate charged to Victorians for the same journey. On the return journey from Melbourne the difference was even greater. (Clark1971p316)

At the Melbourne session of the convention the provision regarding the regulation of the rivers which had emerged from the Adelaide session, was struck out in the expectation that it would be replaced by something more satisfactory. However the delegates failed to agree on a replacement. The impasse was broken when Edmund Barton persuaded his fellow delegates that South Australia's interests in navigation would be protected by the Commonwealth Parliament's general power to legislate with respect to trade and commerce. Barton based this view on a memorandum prepared by the Tasmanian, Inglis Clark. He argued that it was clear from American precedents that the general federal power to regulate trade and commerce with other countries and among the States, amply covered the use of navigable rivers as highways for commerce. The delegates made this explicit by the inclusion of what would become section 98.

Concerned that New South Wales' right to develop the Murray system within its borders was now in doubt, Reid proposed the following restriction to the power of the Commonwealth to make laws with regard to shipping and navigation.

> *The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the use of the waters of rivers within its borders for conservation or irrigation.*

The South Australians responded that this would allow New South Wales to drain the Murray dry. Intense debate ensued. The phrase *within its borders* was soon dropped. After weeks of debate the final wording emerged seemingly almost by chance. Because of its importance and as an example of the provocative way Reid participated in the debate, the official record is worth quoting at some length.

> *Mr Reid – I am very anxious to protect the rights of every one. It only happens that we, by some misfortune of nature, have more rights than other people because we have more water and longer rivers. It is a great misfortune, but we could not help it, I assure honourable members. It has been the subject of great vexation to our friends for years past. I am prepared to add any words to remove difficulties. I am prepared to leave out the words 'within its borders'. I will adopt any amendment to make it of general application.*
>
> *Sir John Downer – Do you object to 'reasonable use'?*
>
> *Mr Reid – I do not know that I would in the interests of a settlement of this vexed question. I will take a moment to consider the effect of inserting those words, and when I move my amendment I will probably be found to have inserted them.* (Official RecordVol.2p1987)

Then Reid pulled back, but the mood of the convention had finally moved against him after weeks of debate. As a result the rights of States to use the water of their rivers for irrigation was now to be subject to the proviso that the use had to be 'reasonable'. Subsequently, at the closed conference of premiers held in Melbourne in early 1899 to further amend the draft constitution, Reid sought extra concessions regarding the use of river waters but was unsuccessful.

## 4. SITUATION AFTER FEDERATION

After the new national constitution came into force in 1901 the rights, responsibilities and powers of the various jurisdictions with regard to the Murray became very unclear. Immediately after the convention the South Australians had been particularly disappointed. Looking at what had been gained through section 98 and seemingly taken away by section 100, Sir Josiah Symon commented *Gentlemen you have given us the rivers but you have taken away the water.* Those sections of the constitution most relevant to the Murray were 98, 100 and 101. The latter dealt with the establishment of the Inter State Commission, a body that was to arbitrate on a range of inter-state disputes. (See end note for the text of the three sections) It was section 100, however, which has attracted the most attention.

In 1902, speaking in the House of Representatives, Alfred Deakin told his fellow members that section 100

> *is probably the most complex - I would also say the most obscure - part of the whole constitution and it will be extremely difficult to determine first, what are our rights and*

> *powers, and next, the most tactful and effective way of asserting them* .(Clark 1972 pp337/8).

On 17/12/1902 *The Advertiser* commented that attempting to resolve these issues meant that *lawyers would taste paradise*.

More recently the constitutional historian W.G. McMinn commented that the effect of adding 'reasonable' to section 100:

> *was virtually to destroy the proviso, because it meant that the constitution would not give legal precedence in any conflict of interests. The best New South Wales could hope for, it seemed, was continuous litigation to define "reasonable" in every place and circumstance* (McMinn 1979 p115).

However, even during the early days of the new nation there were at least some people who saw an alternative to the judicial process for dealing with 'the rivers issue'. They argued that the matter was inherently political and should be dealt with by elected politicians negotiating solutions and not by the courts. In the immediate period after federation the most authoritative interpretation of the constitution was provided by Sir John Quick and Robert Garran. Both had been first hand observers at the constitutional convention and significant participants in the federation process. In their magisterial *The Annotated CONSTITUTION of the AUSTRALIAN COMMONWEALTH*, they wrote that the intention of the writers of the constitution was to give some protection to both uses, navigation and irrigation, but not to allow either use to force out the other (Quick and Garran1901p890).

That still left open the question as to how best to determine priority. Quick and Garran proposed a public interest test. They asked whether it would not be better, instead of giving preference to one use or the other, that *the public interests as a whole ... be considered, by balancing the requirements for both purposes, and regulating the use of the water according to the relative importance of the two purposes* (Quick and Garran 1901 p893). It was clear to Quick and Garran, that the non-judicial activities of adjudication and administration would be central to the process, and so they suggested that the issue would be best handled by the Inter-State Commission when it was established. The subsequent fate of the Inter-State Commission at the hands of the High Court should not obscure their basic point: that on this issue, as with many others, the constitution had created a tension or conflict which was best managed by elected politicians rather than judges.

This was also the position taken by Isaac Isaacs near the end of the debate on the River Murray question, just before the compromise that produced the final wording of what would be section 100. He argued that the Supreme (later High) Court should restrict itself to considering legal issues and avoid making political decisions. Isaacs asserted that water use was *an absolutely political question to be determined by the extent of territory, the quantity of water and the needs of the population* (Official Record Vol.2 p1895). In 1904 Isaacs was retained by the South Australian government to provide advice regarding the legal options available to support their position on the River Murray question. Isaacs agreed that they could mount a strong case in the courts. However, he urged that there was no necessity for *transferring the consideration of the great question how best to utilise our river water from the executive to the judiciary*. He concluded by urging South Australia to persist in seeking a political solution (Clark 1972 p381).

Since federation it has sometimes been suggested that the inter-state political and administrative processes put in place to manage the River Murray have been required because the drafters of the constitution failed to negotiate a clear constitutional settlement to the River Murray question. However, for at least some of the drafters, the eventual result was as it should be. Looking at the history of conflict over the future of the Murray since federation, it is hard to deny Isaacs' contention that water management is fundamentally a political matter. Given that starting point, it can be argued that people involved in water management should not see themselves as working in a situation of unnecessary complexity created by an unresolved constitutional question, as many do. Whether elected politicians, agency staff or community representatives, they are taking part in the often messy, never ending process of defining the public interest. This is fundamentally a political activity that needs to take account of society's changing priorities and values. Assigning such a process to the arcane, often conservative and frequently unpredictable workings of the courts seems a dubious option, with serious risks for both the judicial and parliamentary systems.

## 5. END NOTE

Three sections of the Constitution of particular relevance to the 'rivers issue'.

s98 The power of the parliament to make laws with respect to trade and commerce extends to navigation and shipping and to railways the property of the state.

s100 The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a state or of the residents therein, to the reasonable use of the water of rivers for conservation or irrigation.

s101 There shall be an Inter-State Commission, with such powers of adjudication and administration as the parliament deems necessary for the execution and maintenance, within the Commonwealth, of the provisions of this constitution relating to trade and commerce, and of all laws made thereunder.

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# Development of stream flow measurement in Australia and beyond: Why, Where, When, How and Who?

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**Summary**
A brief history of the development of streamflow data collection in the world and in particular in Australia is given. It is shown that the measurement of water resources in Australia has been a high priority at different times in the country's development. In terms of world data collection Australia showed early foresight in that water resources data was required for its development. The greatest impact on streamflow data collection has been the lack of financing it. The old civilisations in Egypt and China placed recording of water levels at a very high priority. The forecasting of flows kept the leaders in power by announcing impending floods. Streamflow data collection is essential for the pursuit of sustainability of water resources.

## 1. INTRODUCTION

Hydrometry is concerned with measuring and observing elements of the hydrological cycle. Rainfall and stream-flow measurement are the cornerstones of all the programs that collect basic surface water hydrologic information. We have all looked at flood level marks on the walls in a flood ravaged house, or on a marking post next to the River Murray or perhaps in an Egyptian Temple or on the galvanised dunny out the back (the Australian equivalent of the Nilometers?). We have all played "Pooh Sticks" at some time but how many of us have converted the timing of the travel of the sticks into velocity and then multiplied by area to get flow. This method was used in the colonial days in Australia. The basis of stream-flow gauging is the process of recording a stream height and then translating that height into a discharge volume. This method has substantially remained unchanged for the last century and a half.

The measurement of stage height has been done by means of manual staff gauge reading, automatic chart recorders and finally digital recorders over the years. A number of devices such as ultrasonic meters and electromagnetic meters have been installed to continuously measure velocity and hence determine flow through area times velocity. A potted history will be given of the spread of data collection world wide and in Australia attempting to relate its progress to the needs of the individual countries and states.

## 2. HISTORY OF DATA COLLECTION

Biswas (1970) in his history of hydrology gives a chronology of recorded hydrologic engineering with 3000 to 3500BC given for the Nilometers (miqyas an-Nil) to record the fluctuations of the Nile. Other stations on the Nile date back to 1800BC for Nilometers at the Second Cataract in Semna. There were a number of different methods of measuring the flood levels including just marking the cliffs, marking steps that led down to the river and the third of conduits bringing water to a cistern or well. This third system parallels modern day float wells. The Roda Nilometer has the longest continuous record of minimum and maximum levels which Jarvis (1935) presented for the period 622 AD to 1926 AD. Another aspect of the Egyptian data collection system was the use of fast rowers and horses to convey whether a large flood in the Nile was to occur in orser for the high priest to forecast whether harvests would be bountiful. Biswas reports that in 1050BC water meters were used at the Oasis Gadames in North Africa but what were they actually measuring?

The Chinese had similar measuring systems to those of the Egyptians dating back to 220 BC and they also used horseman as conveyors of stage height measurements so that the emperor would know whether there was an impending flood.

Leonardo da Vinci in the late 16$^{th}$ century successfully used floats to measure velocity and had a clear idea of the principle of continuity but his notes were not in popular use for hundreds of years. They were used privately by one of his students but remained undiscovered for over a hundred years. Herschy (1999) outlines the development of the current meter used for measurement of velocity. It was developed over a period of 300 years beginning with paddle devices used by Marsigli (1658-1730). A current meter reported by Woltman (1790) was available in the late eighteenth century. It did not come into popular use until the late nineteenth century when a much improved version was available.

At this time the development of stream gauging networks in the US and Australia started to grow in a systematic way. Networks in Europe followed in the early 20$^{th}$ Century. Those countries with flooding problems and/or shortages of water showed most concern for data collection. Elsewhere in the world in response to water resources development there was a rapid increase in the number of gauging stations. Table 1 shows a list of some of the earliest stations throughout the world which have archived stream levels from which flows were developed. The fundamental measurements to develop accurate rating tables are changing as electromagnetic current meters and acoustic Doppler devices are produced.

Usually country networks of stream gauging stations have developed to meet national needs and in recent times networks have been developed for international rivers such as the Mekong River. The growth of hydrological networks for the various European countries follow a pattern similar to that of the Swiss national network over the last 150 years (Rodda, 1999).

There has been
- Flood prevention; 1963 to present;
- Hydropower development and operations; 1908-1960;
- Water pollution control; 1960 to present;
- Water resources management; 1975 to present; and
- Global environmental monitoring contribution; 1985 to present.

In Australia investigations of water resources could be added for the period 1870 to present.

**Table 1:** Commencement Dates of Stream Water Level Measuring Stations

| Country | Earliest Year | Remarks/Events promoting Network Development and Reference |
|---|---|---|
| Scotland | 1927 | Tay River, The Surface Water Year Book of Great Britain, 1971 |
| England | 1851 | River Lee, The Surface Water Year Book of Great Britain, 1971and in Friend European Archive |
| England | 1883 | Thames River at Teddington, The Surface Water Year Book of Great Britain, 1971 |
| Wales | 1879 | Vyrnwy at Vyrnwy Reservoir, Severn River Authority, The Surface Water Year Book of Great Britain, 1971 |
| Denmark | 1917 | Aquatic Environment Nationwide Monitoring Program (1989) 100 new discharge measuring stations Puupponen (1996) |
| Finland | 1847 | Vuoksi Imatra or Imatza In Friend European Archive UNESCO (1997) |
| Norway | 1851 | The oldest discharge station in operation is from 1871. These stations were made for transport purposes, both for ships and for timber floating. Puupponen (1996) |
| Sweden | 1807 | Vanerngota at Vanersborg, Puupponen (1996) |
| France | 1863 | Loire at Blois, Loire at Montjean UNESCO (1997) |
| Romania | 1840 | Danube at Orsova UNESCO (1997) |
| USSR | 1812 | Neman River at Smalininkai UNESCO (1997) |
| Czechoslovakia | 1851 | Elbe at Decin UNESCO (1997) |
| China | 1865 | Yangtze River but ~221BC for Minjiang River |
| New Zealand | 1906 | (Mosley et al, 1992) |
| New South Wales | 1867 | Hawkesbury at North Richmond Bridge. |
| New South Wales | 1872 | Murray at Lock No 10 Wentworth not at Albury on the Murray, as quoted in WCIC, 1971. |
| Tasmania | 1901 | South Esk River at Launceston. Lake Leake had systematic water level data readings from 1884. (Livingston, 1989) |
| Queensland | 1875 | Mary River at Maryborough |
| Victoria | 1864 | Daily Water Level at Mildura on Murray. Water Levels at Echuca in 1865 (different sources give different values) - but flow measurement in 1866 on the Coliban River at Malmsbury in connection with investigations for Bendigo Goldfields water supply (Smith and Weinmann,1989). |
| Western Australia | 1897 | Water supply to gold fields, Helena and Canning Rivers, AWRC (1989). |
| South Australia | 1884 | Torrens River at Gorge Weir |
| ACT | 1910 | Cotter River at Cotter Kiosk Station established after site for Canberra chosen. |
| Northern Territory | 1952 | Todd River (Brown, 1983) |

Note there could be earlier stations than these but their records have not been listed in sources that were consulted.

## 3. AUSTRALIA

Australia's stream gauging network began in the 1860s in Victoria. However there were some earlier records of water levels but these were taken sporadically and unfortunately much of the old data has not been archived and is consequently lost to water resource analysts. The first recorded gauging in Australia by current meter was undertaken in South Australia in 1874.
At the beginning of the 20th century, as existing sources of water came under increasing pressure, the collection of stream level and stream discharge data was given a priority to enable development of the resources. The periods of stagnation or reduction in numbers of gauging stations over time correspond to periods of economic recession and war.

A new era commenced in 1961 with the establishment of the Australian Water Resources Council (AWRC) and the subsequent introduction in 1963/64 of Commonwealth grants for an extended gauging

programme. The following years saw a rapid expansion of the stream gauging networks in Australia.
This period of growth also corresponded with the commencement of the International Hydrological Decade in 1965. In 1975 the AWRC introduced the National Water Quality Assessment Programme which was again subsidised by the Commonwealth Government. In the period 1978 to 1985 there was a withdrawal of direct financial support by the Commonwealth Government for the water resource assessment programs of the states. This resulted in a levelling off in the growth of hydrometric networks and indeed contributed towards a reduction in stream gauging activities that led to a decline in the size of many networks.

Brown (1980, 1983a,b) reported on the dilemma facing Australian governments in the collection of water resources data. The consultant's report to project water demands and supplies for the Water 2000 study highlighted the plethora of organisations that were involved in the collection of water resources data and the variety of methods that were used in converting the data and storing the data. There was a major anomaly in that meteorological data was collected on a national basis but constitutionally water resources information was left to the state governments and the territories.

Figure 1 shows the growth of the stream gauging network in Australia. The decline continues in the decade from 1985-1995. At the same time the introduction of solid state recording devices for hydrological data allowed replacement of chart recorders and far more efficient processing and archiving of data. In the last decade of the 20th century a period of extensive requests for hydrological information to support the ecological and environmental management of river systems was witnessed. The privatisation of water authorities has on the other hand lessened the accessibility of some data and this is an issue that relevant authorities should address.

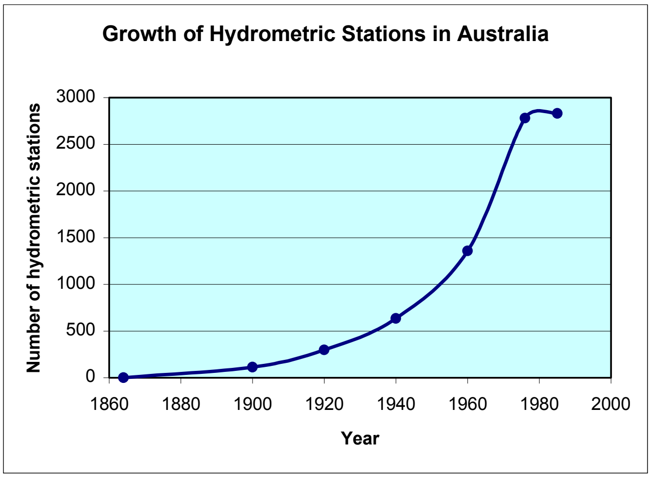


**Figure1:** Growth of hydrometric stations in Australia

It is interesting to note that early collection efforts were state government based for development of navigation on the Murray, water supply for towns, the gold fields, the development of hydropower and irrigation as well as flooding in the Hawkesbury. In Australia there has been a change in the organisations that have been collecting streamflow information with the organisations changing as regularly as flood events occur in Australia, ie a lot more than one thinks as there is a major flood somewhere in Australia every year. Now in most states there is an agency that attempts to bring the state's water resource information together.
Links to these organisations can be made through the Bureau of Meteorology web site
(www.bom.gov.au/hydro/wr/sgc/agencies.shtml.).

Recent advances in hydrometric instrumentation in Australia are given in a paper by Falkland, Daniell, Johns, Malone and White in 1991.

### 3.1 New South Wales

Data on stream water levels in NSW has been collected since 1867 on the Hawkesbury with some flood levels recorded at Windsor from 1799. Daily river heights were recorded on the Darling, Murrumbidgee and the Murray Rivers in the 1880s. A regular program of discharge measurements by current meters did not commence in NSW until 1902. This method of converting stage height to flow superseded the methods of floats and hydraulic formulae that had been used since 1885 in NSW.

The first automatic float recorder system was installed in Australia in about 1910 (WCIC, 1971). The Department of Land and Water Conservation currently operates a network of 300 river stations dropping from a peak number of 700 in the early 1970s. In the last 10 years, due to reduced funding, the number of stations has halved.

### 3.2 Victoria

Smith and Weinmann (1989), of the then Rural Water Commission, stated that Victorian water resource development was started at a significant scale in 1857 with the construction of the Yan Yean Reservoir for Melbourne's water supply. Smaller storages were constructed near Ballarat and Bendigo to provide a much needed water supply to the goldfields a few years later.

These early water development activities were paralleled by efforts to ascertain the volume of streamflows available for water supply. The first water level observations were undertaken in 1864 on the River Murray at the Old Mildura Station but the first known stream flow measurements were undertaken in July 1866 on the Coliban River at Malmsbury in connection with investigations for the Bendigo Goldfields water supply. *The Irrigation Act 1886* signaled the commencement of organised stream gauging in Victoria and by the year 1888, 17 rivers were gauged at 27 points. In 1890 the requirement for the collection of streamflow data was formally included in legislation.

### 3.3 South Australia

In the history of water in South Australia (Hammerton, 1986) there is little reference to the measurement of stream-flow. Obviously the development of water resources was based on little measured stream-flow or the records have been lost. In the 1860s through to the 1880s there were investigations of stream-flow by individual pioneers (Hammerton, 1986) which were undertaken to meet their own needs. This information was to be used in official surveys later but who were these official surveyors and how was it carried out? There was no plan for the assessment and development of water resources in this colony although it was a much discussed and legislated topic in The House of Assembly. Commissioner Catt noted at a Royal Commission in 1901 that a systematic gauging of streams, which he began in 1887, was soon disbanded when the organisations for managing Water Works were amalgamated in 1888 and 1889. It appears that in 100 years nothing has changed with respect to the measurement of water resources in that it is the first element to be cut when costs are to be reduced. A true economic evaluation reflects that streamflow data collection is an extremely cost effective strategy for providing benefits in design and avoiding flood damage and loss of life. The drought of 1898 to 1902 led to an increased interest in monitoring water resources when there was failure of many of the irrigation and private supplies. Table 2 provides a list of the early streamflow stations that measure water resources of interest to South Australia. Gerney (1962) analysed all available streamflow data to develop relationships for streamflows in SA and concluded that gaugings of streamflow are irreplaceable even in areas of rapid development.

It is noted that there is a lack of stream flow stations in the far north of the state and consequently the variable behaviour of most of the state's rivers and creeks is not measured. The Bureau of Meteorology on the other hand as part of its flood forecasting responsibilities has developed a considerable network in the Adelaide Metropolitan area and adjacent Mt Lofty Ranges.

**Table 2:** Earliest Stations of Importance to South Australian Water Resources (from Dept of Water Resources Archive)

| Site | Station Name | Commenced | Ceased |
|---|---|---|---|
| AW004505 | PEKINA CREEK @ Orroroo | 01/01/1888 | 01/01/1889 |
| AW409200 | MURRAY RIVER @ Echuca | 01/01/1865 | |
| AW414203 | MURRAY RIVER @ Euston (1110 Km) | 01/01/1872 | |
| AW425001 | DARLING RIVER @ Menindee Town | 01/01/1881 | |
| AW425008 | DARLING RIVER @ Wilcannia Main Channel | 01/01/1886 | |
| AW425010 | MURRAY RIVER @ Lock 10 (825 Km) | 01/01/1872 | |
| AW426900 | MURRAY RIVER @ Renmark Town Gauge (567.4km) | 01/01/1891 | |
| AW426901 | MURRAY RIVER @ Morgan (319.5 Km) | 01/01/1886 | |
| AW503500 | ONKAPARINGA RIVER @ Clarendon Weir | 01/04/1889 | |
| AW504501 | TORRENS RIVER @ Gorge Weir | 01/01/1884 | |
| AW504509 | HOPE VALLEY RESERVOIR INTAKE @ Athelstone | 01/01/1889 | |
| AW505501 | SOUTH PARA RIVER @ Barossa Diversion Weir | 01/01/1889 | |

### 3.4 Tasmania

The early records from Tasmania consist of intermittent observations of water level data from Lake Leake in 1884. Streamflow measurements were however undertaken by C. J. Burke on the Ringarooma River in 1885 where he was investigating water allocations for sluice mining. Launceston Council has the honour of beginning the first set of daily river water level readings of the South Esk River in 1901 (Livingston, 1989). A Mr Rahbeck recorded levels of Lake Sorrell and Lake Crescent in 1901 and 1902. He also carried out stream gauging in the Central Plateau and North East while investigating hydroelectric schemes. The plea for a systematic recording of stream flow was made to the Tasmanian Parliament in Rahbeck's report. Nothing was done. It was not until 1920 that an officer was made available for general river gauging in the Hydroelectic Department and by June 1922 seventy gauges were in operation (Livingston, 1989). The Hydroelectric Commission are extremely active in maintaining the network for operation of their facilities.

### 3.5 Western Australia

Stream gauging in Western Australia commenced in 1897 when temporary river gauging stations were established on the Helena and Canning Rivers to assist in the planning of the Goldfields Water Supply Scheme. Between 1908 and 1911 a further nine river gauging stations were established on local hills streams to assess potential water supplies for Perth. No further network expansion took place until 1939-40 when nineteen stations were established on some of the principal rivers in the South West of the State. The South West has most of the State's population, agriculture, industry and forests. The early gauging station establishment was primarily a reflection of the State's growth and water supply needs in this region. In the 1950s and 1960s water resources assessment began in the northern Indian Ocean and Timor Sea areas. The need was again to supply information for development and water supply projects that were being planned. The quality of this early record was poor and characterised by long and/or frequent periods of missing record, often when significant flow events occurred. The stations were generally not the most suitable for accurate streamflow measurement as they were frequently located for convenience of access, at road and rail crossings. Commonwealth funding to State Governments gave the first real impetus to develop a planned gauging network to meet a wider range of needs for hydrometric data. Consequently rapid growth in gauging station numbers occurred in the mid sixties through to the late seventies. By the late 80s there were 261 stations operating to provide flow data and 51 stations for level only data (AWRC, 1989). The vast majority of these stations obviously have been operating for a relatively short period. Again cut backs in funding led to a rapid demise of the number of gauging stations in the late 1980s and early 1990s. It is interesting to note that with the large number of tropical cyclones in the north west there has been considerable damage to road and rail infrastructure due to floods. Improved designs need analysis of past flood information and the gauging network in this area would therefore have a very high benefit cost ratio. Private mining companies are now collecting their own hydrometeorological data.

### 3.6 Queensland

Mary River at Maryborough has recorded stage height dating back to 1875. The network up to the turn of the 20$^{th}$ century consisted of a small number of stations on the major coastal rivers. It was a feature of most stations that while height was being recorded satisfactorily many stations were poorly rated and only a low level of confidence could be placed in flood discharge levels (Hausler and Coe, 1989). Boughton (1999) stated that the first measurements of streamflow in the Brisbane River were carried out at Lowood in 1909. Manually read staff gauges were used then to measure the stage height of the river. The network in Queensland consisted of more than 600 stations in the early 1980s.

### 3.7 The Australian Capital Territory (ACT)

The site for Canberra was based on the requirement of having a reliable and pure water supply and the agreement for this was ratified in 1909. The first stream gauging station was established on the Cotter River at Cotter Kiosk in 1910. Another water source for Canberra the Queanbeyan River, had a gauging station established at Googong in 1912. Googong Dam was built over this station in 1976. The gauging station network in the ACT is now operated by ACT Electricity and Water (ACTEW) and is fully automated and largely telemetered. The data archiving system HYDSYS was established in the mid 1980s in the ACT and subsequently spread to all mainland states in Australia.

### 3.8 Northern Territory

The territory was quite late in developing a stream gauging network with its first station being developed on the Todd River for investigating water supply for Alice Springs. There was a rapid increase in the number of stations in the 70s and 80s as major mining developments were proposed and undertaken.

## 4. THE UNITED STATES' EXPERIENCE

The first stream gauging began in the US in 1851. A major study by Humphreys and Abbot on the Mississippi delta led to a report in 1861, which encapsulated the rigorous approach that was undertaken. By 1888 the Director of the US Geological Survey was promoting training of personnel in methods of stream gauging. This was a significant step in enabling a nation-wide stream gauging program to be launched in 1894. In the introduction to the book on Streamflow by Grover and Harrington (1966), which was a reprint of a 1949 edition, Ven Te Chow commented that a revolution was happening in the US Geological Survey with approximately 3000 of the 12000 gauging stations in the US being converted to automatic digital recorders. It was felt that this program of having gauging stations automated would ensure significant manpower savings, better accuracy and timeliness of publication of the data. Ven te Chow was talking about paper tape punch digital stage recorders. This revolution did not last long as the solid state recorder took over. The USGS has made available its very large database of streamflow data to any Web user.

## 5. CHINA

Rainfall gauging in China can date back to the Shang Dynasty (~1766-1050BC) more than 3000 years ago. River stage observations began in the Qin dynasty (221-207BC) with three stone statues erected at Dujiangyan Weir on Minjiang River. Rivers such as the Yangtze had gauges set up at the various harbours along the river in the mid to late 19$^{th}$ Century. The earliest one is the Jianghan Custom water gauge set up in 1865. There has been a rapid increase in the number of reporting stations since 1950 and for the Yangtze catchment there are over 1000 stations (Cheng, 1999).

There has been much research done on flood levels in various river systems in China. In examining flood levels for the Yellow River, Zhao and Yang (1999) reported on the "Mark Stake" at Xiakou. Similar systems to those used in Egypt were used to forecast floods. Horsemen were used to report impending floods in the Ming dynasty (1368AD-1644AD) especially between Tongguan and Suqian. Emperor Kanxi in 1709 issued an imperial edict to set up a flood measuring and reporting station in Xiakou. Since that time it has become one of the principal reporting stations on the Yellow River. The flood reporting system lasted more than 200 years until the end of the Qing Dynasty (1644 AD-1911AD).

## 6. SCANDINAVIAN COUNTRIES

A report of the project "Hydrometric network analysis" which was initiated by the heads of the hydrological institutions in the Nordic countries (the CHIN-group) in

1990 describes how the institutional background of hydrometric monitoring varies as greatly between the Nordic countries as it does between states in Australia. In Denmark and Finland, the national hydrological services work under the Ministry of the Environment, whereas in Iceland and Norway these institutions are operating in the energy administration. Sweden follows a third model where the hydrological and meteorological services are united. Hydrological investigations in Greenland are carried out by a unit under the Department for Public Works and Transportation. In 1995 the total number of national hydrometric stations in the Nordic countries was almost 4000. .More than half of the stations were situated in Norway, where the role of hydro power production is very important. Norway had some 770 discharge stations and 1290 water level stations within its national network. Finland had about 700 national stations, and in Denmark and Sweden the figure was some 450 due to a much smaller number of water level stations. The Icelandic network comprised more than 150 stations, and the number of operating stations in Greenland was very low, only 15. Less than one third of all the stations which were classified as national were owned and financed by the hydrological institutions. Among other types of organizations, the role of the hydro power sector was particularly strong. In 1995, one third of the monitoring stations which were owned by the national services were using digital technology: they were either telemetry stations or they had local data logging. Among the other groups of organizations the technical standard was even higher. Four out of the five countries used Acoustic Doppler Current Profiler techniques for the measurement of river discharge. The total annual costs of the Nordic national hydrometric monitoring systems can be estimated to be almost 10m Euros. The average cost of operating a station with data logger was more than six times higher in Greenland than in Denmark and Norway .In this case, the role of logistic costs was crucial. A similar experience to outback Australia?

## 7. DATA ARCHIVING

Many organisations in the 60s and 70s developed their own computer main-framed based systems for archiving streamflow information and other water resources data. Systems for event recording digitally were initially developed on paper tape (Goodspeed and Savage 1969) and then subsequently using data loggers. There was a need for a better system of checking and validating the input data and a Rimco strip-chart conversion unit provided water authorities with a convenient method of processing charts in Australia. Goodspeed and Savage, 1968) A computer programming system for treating the coded output of this machine was developed by CSIRO in parallel with the mechanical development of the equipment.

There was a major recommendation from the National Workshop on Surface Water Resources Data (AWRC, 1984) that each state be encouraged to develop comprehensive, integrated, readily accessible and freely available water data bases. Each state was going their own way and there was little support for the development of a common data archiving system. The ACT, under the guise of promoting leading technology enlisted the support of Peter Heweston to develop a PC based system HYDSYS (Daniell and Heweston, 1988) for archiving water resources information. This replaced the CSIRO Edtrace system. The new system was quickly taken up by a number of organisations including CSIRO, NSW Water Resources Commission, WA Public Works and E&WS (SA). Tasmania under the auspices of the Hydro went their own way with TimeStudio and have successfully marketed that system internationally. As of October 2001 Hydsys Pty Ltd will be owned by the Hydro.

## 8. PUBLICATION OF STREAMFLOW RECORDS

The use of the web has seen a marked increase in the accessibility of streamflow records around the world. On-line data for many stations now exist but, at the same time, there has not been a concerted effort to maintain the hydrometric system and ensure that there is adequate gauging to validate rating curves and ensure quality of the streamflow records. The Water and Rivers Commission of Western Australia has easily retrievable streamflow data for all of its stations available on the web, as does the Queensland Department of Natural Resources and Water. The Bureau of Meteorology has a site called Streamgauging Information Australia whereby operating stations can be found with meta-data of those sites. Another facet of the web is on line telemetered data and this is available both through the Bureau of Meteorology and individual authorities in Australia.

On the international level there have been a remarkable number of changes with many databases of streamflow information available over the web.

## 9. CONCLUSION

It is of concern to me that small changes due to climate change are being investigated and outrageously funded when the basic runoff data has increasingly larger confidence limits around it. The fundamental measurements to develop accurate rating tables is changing as more electromagnetic current meters are produced, but there still has not been developed a single one stop measuring system that can be located remotely and measure flow. There have been ultrasonic systems but of varying quality and not suitable for use in remote regions.
The collection of streamflow data for water resources assessment is of course crucial to the well being of all and to the sustainability of this resource.

When it comes to streamflow data collection short term priorities have ensured that long-term understanding has been diminished. To quote Rodda (1999):
"*How much easier it is to sit in front of a colour monitor in a cosy office and peer at the real world of hydrology on the screen in order to refine a model, than to capture measurements under difficult field conditions!*"

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# Lake Victoria: Different perspectives and changing priorities

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**Summary**
Lake Victoria was commissioned as a regulated water storage in 1928. Since then it has been a central component of water supply to NSW, Victoria and South Australia. It is operated as a water storage, and is also used to improve water quality, provide environmental flows and enhance the efficiency of water delivery. The Lake is also an important cultural heritage site for the Aboriginal community, containing physical traces of human occupation, including the burial grounds of Aboriginal people, dating back 18 000 years. While underpinning development along the River Murray, operation of the Lake has also had adverse impacts on the cultural heritage and landscape at Lake Victoria. Since 1994, the MDBC has spent nearly $8 million on the largest single cultural heritage conservation project in Australia, while continuing to manage the Lake as a water storage facility. Community awareness and meaningful involvement in decision making have been key components in seeking a foundation for the future management of the Lake.

## 1. INTRODUCTION

> *... we came upon a most magnificent lake - known as Lake Victoria. ... where we came on it the banks presented nothing but park-like scenery - groups of gum trees most tastefully disposed. It is certainly a most enchanting spot - the expanse of water, on which are innumerable waterfowl, the majestic swan, the screaming long-billed "Navarete" and beautiful spur-winged plover, forms a beautiful picture. (Sturt, Journal 12 September 1844)*

This was how Captain Charles Sturt described his first sighting of Lake Victoria. There was a relatively large Aboriginal community living in the area at the time of first European contact and there is archaeological evidence of continuous occupation by Aboriginal people at the Lake for about 18 000 years.

Since European settlement, the landscape at Lake Victoria has undergone many changes. After initial contact, the overlanders used the Lake in the 1830s and 1840s as part of their route to South Australia. Later, the area was opened up for pastoral leases, and is still used in this way. In 1919, work commenced on construction of "Lake Victoria Storage", the first of four off-river water storages in the plan to regulate the Murray and Darling rivers for transport and agriculture. The Lake was subsequently commissioned in 1928. Since then, the extra capacity and the ability to guarantee water resources enabled the development and expansion of agriculture and industry along the Murray, and further afield in areas such as Adelaide and the northern Spencer Gulf in South Australia.

At the same time, regulation of the Lake has adversely impacted on the cultural and natural heritage values of the area. Under natural conditions, the level of Lake Victoria ranged from a normal low level of about 21 metres AHD to the highest recorded flood level of about 26 metres AHD in 1890. Following regulation, the full supply level of the Lake was raised to 27 metres AHD, flooding much of the areas previously occupied by humans. The Lake was also held at high levels for extended periods of time, causing the trees to drown.

Community attitudes regarding developments and their impact on environmental, social and cultural values have changed in the years since the Lake was regulated. The presence of burials at Lake Victoria has long been known, but it was not until 1994 when the Lake level was lowered to undertake works to the control regulator, that the real extent was realised. Since then the MDBC has engaged in a significant community consultation process to protect the burials, minimise further damage to cultural heritage and improve the surrounding environment. This included a major environmental impact study (EIS) in 1997-98 which identified and examined the competing interests surrounding Lake Victoria.

As a result of the EIS, the MDBC was granted a Consent under Section 90 of the New South Wales *National Parks and Wildlife Act 1974* to 'destroy, deface or damage an Aboriginal place or relic' in 1998. This recognised the critical role of Lake Victoria to water supply, and permitted the continued operation of the Lake Victoria as a water storage. It also recognised the significance of the cultural heritage present at the Lake, and included a number of conditions intended to minimise the impact of Lake Victoria's role as a water storage on cultural heritage. This has not only forced changes to the way Lake Victoria is managed as a water storage, but has also involved a development in the way the MDBC and SA Water relate to the community.
Lake Victoria therefore provides an excellent case study in retrospective application of contemporary values on

[1] *The views expressed in this paper do not necessarily represent those of the Murray-Darling Basin Commission nor the Murray-Darling Basin Ministerial Council*

existing operations. The MDBC has undergone an expensive but nevertheless worthwhile process to respond to the situation and there are a number of lessons which can be drawn from the experience and can also be applied to similar situations, and developments in general.

### 1.1 Aim

The aim of this paper is to identify the key messages from the Lake Victoria experience.

### 1.2 Scope

The paper will provide some background including the geography of Lake Victoria and the various ways Lake Victoria has been used and viewed by different groups of people and the value these groups have attributed to the Lake.

The changes resulting from the Section 90 Consent represent a transition from the post-regulation, single focus use of the Lake as a water storage to an attempt to balance several uses and values. This was, and continues to be, a difficult process which will be examined in some detail and some key messages will be identified.

Finally, the paper will look to the future. What challenges are in store and how will we incorporate the lessons learnt so far in searching for ways to deal with them?

## 2. BACKGROUND AND HISTORY

### 2.1 Geography

Lake Victoria is a naturally occurring lake situated in far south-western New South Wales five kilometres north of the River Murray, as shown in Figure 1. The Lake is 13 kilometres long and 10 kilometres wide, with a circumference of 41 kilometres. Frenchmans Creek flows into the Lake from just upstream of Lock 9, and Rufus River flows out of the Lake, re-entering the Murray just below Lock 7. Even though the Lake is situated in NSW, the lakebed is owned under freehold title by South Australia. The water in the Lake is under the control of the MDBC and regulated under the *Murray-Darling Basin Agreement* by SA Water.

### 2.2 Lake Victoria - pre-regulation

Traditionally, Lake Victoria was part of the country of the Maraura people, a sub-group of the Barkindji. Maraura country lay to the west of the Darling, running north of the Anabranch to the Chowilla area in South Australia, and then back along the Murray to its junction with the Darling. Hence Lake Victoria was an important part of the network of Aboriginal settlements and trading relationships from the Murray mouth to the upper Darling.

There is significant archaeological evidence of Aboriginal occupation and use of the landscape at Lake Victoria. Figure 2 shows a more detailed map of the Lake. It is believed that Aboriginal people probably camped everywhere around the lake shore but especially along the Frenchmans-Rufus channels and the Frenchmans Islands of the southern lake bed, where the greatest numbers of intact fireplaces, shell middens, huts and clusters of grindstones can be found. There are also significant burial grounds, particularly along the southern lakeshore and on Talgarry Barrier.

The landscape also has a spiritual significance for Aboriginal people as it features in traditional storylines telling of the deeds of great cultural figures such as Eaglehawk and Crow and Nurelli, and of the creation of the lower Murray and Lake Victoria.

This traditional pattern of life was disturbed by the arrival of Europeans in the 1830s. The main impact was initially from overlanders moving herds of sheep and cattle along the River Murray. The Aborigines engaged in a strong resistance which culminated in 1841, following a conflict known as the Rufus River Massacre, on 27 August. The strength of opposition to the European settlement can be seen as a mark of the value of the Lake and its environs to the people. The Rufus River Massacre and other conflicts in the area increase the special spiritual significance of the Lake for the Aboriginal people now living in the area.

The land was subsequently taken over for pastoral leases and many of the Maraura people worked for the pastoralists. However, by the 1890s only a small number of local Maraura people remained in the area. Around the turn of the century, Harry Mitchell, a Barkindji man from the Middle Darling area moved with his family to Lake Victoria, setting up camp at Lake Victoria Station where he worked for many years. Many of the Barkindji families now associated with Lake Victoria are descendants of Harry Mitchell.

### 2.3 Regulation - 1994

Construction of the “Lake Victoria Storage” began in 1919 and involved the construction of 52 kilometres of levees with three regulators to control the water, giving the Lake a maximum depth of eight metres, or 27 metres AHD, with a storage capacity of 680 gigalitres which was almost double it previous capacity.

Since 1928, Lake Victoria has played a key role in water supply regulation, salinity mitigation and environmental flow management of the Murray-Darling system. South Australia is guaranteed a minimum monthly flow under the *Murray-Darling Basin Agreement*, except under very dry conditions. Without Lake Victoria, it would be necessary to more frequently restrict diversions to NSW and Victoria in order to ensure that South Australia received it entitlement flows. The regulation of the River Murray, and Lake Victoria’s role in this system, has underpinned the development of agriculture and industry along the Murray and much further afield.

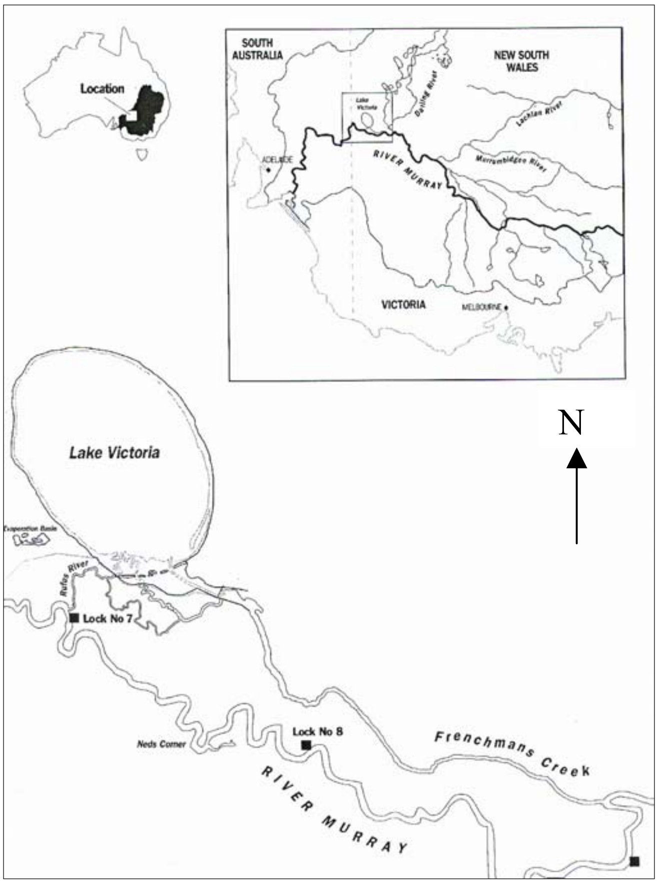


**Figure 1:** Location of Lake Victoria

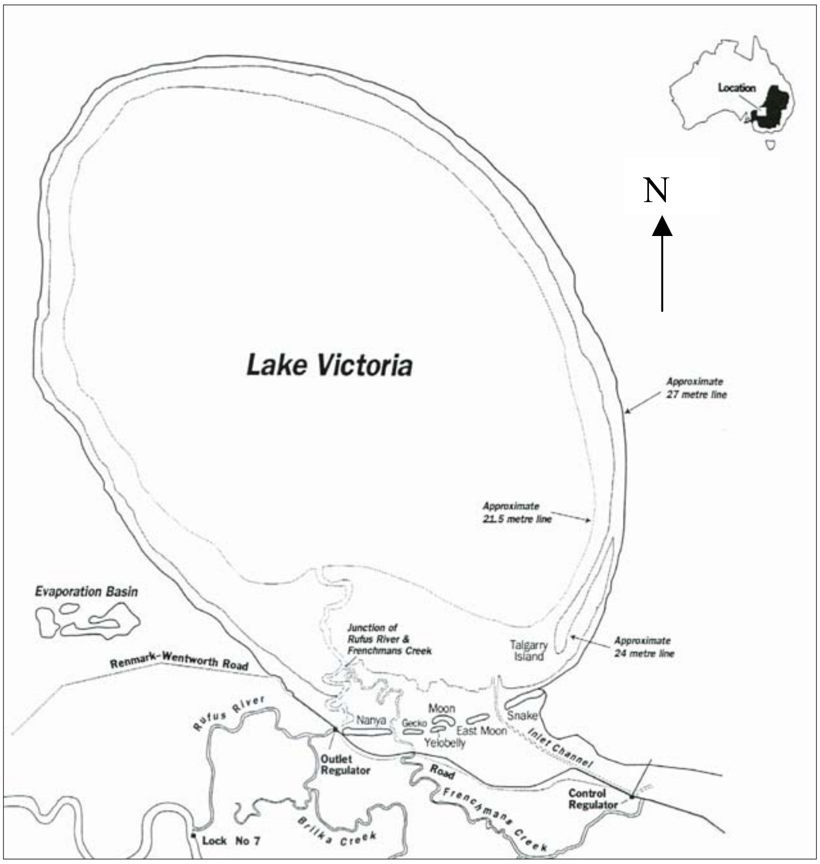


**Figure 2:** Detailed map of Lake Victoria

Construction of the storage with all the various structures and levees, significantly altered the landscape at Lake Victoria, such that they are now the predominant features. In addition, the areas between the 21 and 27 metre levels which were previously above the water line, or only occasionally inundated, were now inundated on an almost permanent basis. This included most of the sites of Aboriginal occupation, including campsites and burials.

Since regulation until the mid 1990s, Lake Victoria has been operated purely in its role as a water storage, with a prime focus on water conservation and later also on water quality. Historically, the Lake has been filled during the winter-spring season and drawn down during summer-autumn as it supplies the bulk of water to South Australia. Consequently, there have been long periods of high water levels, especially in the 1940-50s, which is when it is thought the trees died.

### 2.4 Perspectives

> *The value of Lake Victoria differs for each group of stakeholder. For example, the Aboriginal community values the Lake because it represents their cultural heritage and spiritual connection with the land. Irrigators throughout the River Murray system value the Lake because it is vital to their livelihoods. The stakeholders' perspectives and views regarding the Lake reflect these different values, and define the key issues at the centre of the debate about its management.* (MDBC 1998 pA20)

As summarised by this quote from the EIS Report, the debate surrounding Lake Victoria is founded on the differing perspectives and values of the different stakeholders.

As well as the negative impacts on the cultural artefacts at the Lake, the natural environment had been substantially altered and degraded by the effects of regulation. A further effect of the different uses of Lake Victoria is the change in the perception of its status as a place in its own right.

Prior to regulation, Lake Victoria was probably significant to a relatively small number of people who lived locally, such as the Aboriginal people and later, the pastoralists. Although for different reasons, the Lake probably had intrinsic value for both these groups.

As Lake Victoria became a key part of the water supply system, it developed a significance for a far greater number of people, dependent on the water for agriculture, industry and domestic consumption in places as far away as Adelaide and Whyalla. Some of the beneficiaries may not even have heard of the place itself and its significance to them was more for its value as a resource.

As well as water consumers, the predominant present day stakeholders in the Lake Victoria debate include local Aboriginal people and local landholders. Despite the dislocations which have occurred over time, local Aboriginal people still maintain their association with the Lake. As mentioned earlier, many of them are descendants of Harry Mitchell and were born or grew up around the Lake. The presence of large numbers of burials is a constant and highly visible reminder of the cultural and historical significance of the area, and emphasises their feelings of loss and dispossession.

There are also a number of properties which abut the Lake, Frenchman's Creek or Rufus River and which use water from the Lake or the Frenchmans Creek to support their livelihood and are affected by Lake operations. Some of the current landholders have been on their properties for several generations. Other families who used to live near the Lake remain in the local area.

For these last two groups, the Lake and its environs most definitely have value in its own right. There is no doubt that the operation of Lake Victoria as a water storage has enabled enormous economic benefit to a large sector of the community, but this has been at a cost to a smaller number.

## 3. BALANCING THE VALUES

### 3.1 1994-1998

Table 1 gives an outline of events from 1994 to 1998.

In 1994 the Lake level was lowered to allow maintenance on one of the regulators, and the MDBC commissioned an archaeological survey. Over 300 burials were recorded on the Frenchmans Islands, and the possible number of individual burials was estimated to be between 6 000 and 16 000. The MDBC immediately initiated measures to protect the burials, focussing on physical protection works over what appeared to be the most significant areas. The MDBC engaged the community from an early stage, consulting Elders from the local Aboriginal community and involving them in decision making in relation to protection of the burials. Local Aboriginal people were employed to undertake the works.

Right from the start, there was a fundamental division of opinion within the local Aboriginal community about whether water should be permitted to cover the burials. While most of the Elders would have preferred the burials had not been inundated in the first place, they also recognised the key role of Lake Victoria for water supply, and that so many people were now dependent on the resource the Lake provided. Their focus was on protecting the burials and minimising further damage. This section of the community also recognised that inundating the burials had provided a measure of protection for the artefacts against souveniring, as people so inclined could not access the sites. Conversely, a group within the community strongly opposed covering the burials, as they believed this to be unnatural inundation, and as such, desecration.

**Table 1: Outline chronology of events 1994-1998**

| **1994** |
|---|
| • Lake level lowered for maintenance.<br>• Archaeological survey.<br>• Consultation commenced with Elders.<br>• Aboriginal community opinion divided about whether water should be allowed to cover burials.<br>• NSW Aboriginal Land Council (ALC) involved on behalf of Elders opposed to water covering burials. |
| **1994-1995** |
| • Restrictions on water levels applied.<br>• All exposed burial sites protected.<br>• 1995 draft Management Plan for Frenchmans Islands presented to Elders, but not accepted.<br>• Large scale protection works constructed on Gecko and Snake Islands.<br>• Further large scale protection works planned. EIS required, commenced 1996. |
| **1996** |
| • Division in community widens, Elders opposed to covering burials distance themselves from consultation process.<br>• NSW ALC argues that cultural material on Talgarry Barrier would be disturbed if water level raised above 23.6 metre level.<br>• NSW NPWS advise MDBC s90 Consent required to operate lake Victoria above 23.6 metre level.<br>• More extensive EIS required for s90 Consent, 1996 EIS for Frenchmans Islands subsumed.<br>• Community Summit, draft Framework Agreement agreed including formation of Lake Victoria Advisory Committee (LVAC). |
| **1997** |
| • Framework Agreement signed.<br>• Elders opposed to water covering burials resign from LVAC and consultation process.<br>• EIS for s90 Consent commenced, completed 1998. |
| **1998** |
| • Consent granted August 1998, MDBC Appeals |

The focus of protection works in this early stage was on the southern Lake bed, and the Frenchmans Islands. The main damage to the burials was caused by erosion of the lakeshore due to the impacts of waves on the shoreline, and wind when the water was low. In 1995, a draft management plan was developed, proposing long term protection measures for Snake Island and the Frenchmans Islands, ongoing monitoring and maintenance of the sites, and a cultural heritage training and employment program for the Barkindji community. This management plan was ultimately rejected by the community.

In 1995 and 1996, large scale protection works were constructed at Gecko and Snake Islands. Further large scale protection works were planned for the Frenchmans Islands, which involved nourishment of the sites with approximately 30 000 $m^3$ of sand from Lake bed. An EIS was required for this activity and was commenced in 1996.

In 1996 further investigations at lower levels of the lake shore revealed extensive cultural artefacts such as shell middens, hearths and stone tools, which were not as easy to protect as the burials. The NSW ALC put forward a case that these artefacts may be disturbed if the water level was raised again. As this would constitute “knowingly” causing damage to the artefacts, the NPWS informed the MDBC that it would need to seek a consent to “destroy, deface or damage” under section 90 of the *National Parks and Wildlife Act 1974*. An EIS was also required to support the application for the consent. The first EIS for the Frenchmans Islands was then subsumed into this larger requirement, and not completed.

Community consultation continued throughout this process, although opinion within the Aboriginal community over the issue of water covering the burials continued to be divided. A community summit was held in November 1996 at the request of the Elders, from which a Framework Agreement between the government agencies, and community stakeholders was drafted. This was later signed in February 1997. The Framework Agreement formalised the Lake Victoria Advisory Committee (LVAC), with an independent Chairman, as the ongoing forum for community involvement.

Restrictions on the Lake level applied throughout this period due to legal strategies initiated by the NSW ALC and also to allow protection works to be carried out.

### 3.2 The EIS

It is important to note that the Consent, and therefore the EIS proposal, was only sought in relation to impacts on non-burial cultural material. From the outset, the Commission was, and remains, committed to protecting burial sites.

> *Some values are negotiable and some are not, and this frequently leads to conflict. At Lake Victoria, conflict has essentially arisen because cultural beliefs are clashing with socio-economic values. Given the diversity of interests associated with the Lake, the process of finding a balance has been difficult.*” (MDBC 1998)

The EIS was a complicated process, which revolved around the values attached to the Lake by the different stakeholders. Given the conflicting values, it was recognised early that the process would not be a “win-win” situation, but would require trade-offs.

One problem was that there was very little knowledge available about the impacts of lake operation. A significant amount of benchmark information was collected on many aspects of the landscape. On the basis of this information, the MDBC proposed to operate the Lake at 27 metres for as often as necessary for the purposes of water conservation and in conjunction with this, to operate the Lake so that the drawdown through the 24.5 – 26 metres zone (the elevations where most of cultural material is located) was effected as quickly as possible to avoid impacts from wave energy. The MDBC considered this option provided *the best opportunity to achieve an optimal balance of socio-cultural, environmental and human resource use values of the Lake.* (MDBC 1998 pD55). The MDBC proposal also included the development of an adaptive environmental management plan which would ensure community involvement, continuing physical protection of burials, and measures to minimise the environmental impacts of Lake operation.

During the consultation process associated with the EIS, the division of opinion within the Aboriginal community over whether water should be allowed to cover the burials widened, and those who opposed covering the burials resigned from the LVAC in 1997 and withdrew from the consultation process. They subsequently submitted an application under Section 10 of the *Aboriginal and Torres Strait Islander Heritage Protection Act* seeking protection of the burials from injury and desecration in accordance with Aboriginal tradition. This is still to be resolved, and is in abeyance until the process with the s90 Consent is finalised.

The EIS was completed in 1998, however, the MDBC's EIS proposal was not accepted. Despite the significant protection works and monitoring the proposal also included, it is possible that it may have been perceived by some stakeholders that the MDBC was essentially proposing a "business as usual" option. Instead, NPWS granted a Consent which required a significant change to the way the Lake had been operated historically and which was accompanied by 77 detailed and prescriptive conditions.

The MDBC was concerned that the Consent conditions did not necessarily provide sufficient certainty to allow the MDBC to continue operating the Lake so as to meet its dual responsibility for river health and water conservation. Consequently, the MDBC appealed the conditions in September 1998, but agreed to enter a period of discussion and negotiation to resolve as many of the differences between the Consent conditions and the EIS proposal as possible.

### 3.3 Current management - the s90 Consent

Following the granting of the s90 Consent, there was a period of negotiation which necessarily involved direct dialogue between the regulator - NPWS – and the operator – MBDC. A draft revised Consent with 30 conditions was effectively agreed in June 2000, with the general support of the Aboriginal community. The main effect of the revision was to place many of the prescriptive aspects from the original Consent conditions into a Plan of Management, with the result that the Consent and Plan of Management will form complementary documents. The Plan of Management is still being developed, hence the draft revised conditions depend on the approval of the Plan of Management before they can be signed off.

In the interim, the restrictions which had applied to the level of Lake Victoria from 1996 continued. Initially, the Lake level was restricted to 24.5 metres, but the MDBC successfully sought approval to operate the Lake at higher levels in July 1998. In mid 1999, the Lake level was drawn down to a low level of 21.5 metres as required by the Consent to allow a once-off survey at the very low lakebed levels.

The Consent – both the original and revised conditions – signified a fundamentally different approach to the management of Lake Victoria from that which had occurred since regulation. The main strategy identified by NPWS to protect cultural heritage is by rehabilitation of the lakeshore environs between 24.5 and 27 metres by re-establishing vegetation. This is intended to stabilise the soil and in so doing, minimise erosion in the areas where the cultural material is located. A secondary, but very important aspect, is to rehabilitate the natural environment in recognition of the connection that the Aboriginal people maintain between the landscape and the spiritual significance of the Lake as a place.

There are two basic ways identified to achieve this: removing impacts of stock and non-native animals from the lakeshore, and changing the operating regime for the Lake to allow an annual drying period for the lakeshore. In respect to the first of these, some areas have been fenced off, and alternative stockwatering systems are being provided progressively for the properties surrounding the Lake. Also the uncharacteristic operation from 1996 to 2000 has allowed a substantial natural regeneration of vegetation in some areas of the lakeshore, particularly the southern lakeshore and in areas where stock had been excluded.

Developing the operating regime is an ongoing issue, and is the last remaining issue to be resolved for the Plan of Management. The MDBC has been working cooperatively with NPWS to develop an operating strategy which will provide conditions to allow the survival of the vegetation which has regenerated, as well as promoting further regeneration. However, there is a constant need to focus on the balance between the vegetation requirements and guaranteeing water resources. In doing this, specialist ecological and geomorphological advice has been sought, and extensive modelling undertaken to assess the impacts of the various options on water resources and water quality. A strategy which meets most of the requirements appears possible and is being developed in consultation with NSW, Victoria and South Australia.
Community consultation remains an ongoing aspect of the process. The LVAC meets regularly to discuss issues related to management of cultural heritage at the Lake, and has been intimately involved in the development of the Plan of Management. The MDBC also resources the Barkindji Elders Committee (BEC) so

that its members can consider issues relating to Lake Victoria in a culturally appropriate manner. Members of the Aboriginal community are involved in monitoring and protecting the burials and the BEC are involved in decisions on protection works and other cultural heritage issues.

Keeping the balance is a constant challenge and requires open minds on the part of all stakeholders. It is important to see each specific issue on two levels - both on its own merits, and in the context of the larger picture. Depending on the perspective of the stakeholder, it may appear as if the trade-offs are all one way, and it is important to try and avoid these sentiments. The key to this is information, communication and a willingness to see the other person's perspective.

An interesting example of this was the use of Lake Victoria in October and November 2000 to enhance the flood peaks to South Australia. Additional water was stored temporarily in Lake Victoria, at higher levels than would have been preferred for vegetation and cultural heritage, so that it could be released to coincide with and enhance the forecast flood peaks, allowing overbank flooding in the Chowilla Wetlands and other areas in the lower Murray. This was agreed to by NPWS in consultation with the Elders who appreciated the environmental benefits to areas further downstream.

The Plan of Management is not yet finalised, as the operating strategy is a key component. However, the Plan is largely complete and essentially will formalise the policies which have been developed over the last six years in conjunction with the community and other government agencies. In the interim, SA Water and MDBC are operating the Lake in accordance with these policies.

## 4. KEY MESSAGES

Much of this next section may seem like motherhood statements which can be applied to any development or proposal. This is true - Lake Victoria has many of the same characteristics of any development proposal, perhaps with one basic difference that it is a retrospective application of legislation to a development which occurred more than seventy years ago. In addition, some of the points appear very obvious, but can sometimes be easier said than done, or if temporarily forgotten, can have quite negative effects.

### 4.1 Changes in community attitudes

The regulation of Lake Victoria occurred under different circumstances and societal values from those which prevail now. Community attitudes on indigenous and environmental issues have changed, new legislation has been introduced, and governments have the will to enforce it. These last two points are mentioned separately as the *National Parks and Wildlife Act* which covers Aboriginal cultural heritage, was introduced in 1974, but it was not until almost twenty years later that it was applied to Lake Victoria.

Consequently, the Lake Victoria project has been about redressing the balance from a single focus use of Lake Victoria to a more inclusive approach to land management. The critical importance of Lake Victoria for water resources is recognised by the fact that the Consent was granted, but community attitudes, backed by legislation, no longer accept that it is reasonable to over-ride other considerations completely. In addition, proposed trade-offs must be perceived by the stakeholders as genuine. The conditions which accompany the Consent require significant actions to rehabilitate the landscape where possible, change management practices to minimise further damage and involve people in the process.

There are countless examples where previous practices are now known to have detrimental effects on the environment, and the emphasis in current research is to undo some of the damage where this is possible, and to replace the previous practices with sustainable ones. The broad concept of sustainability encompasses not only ecological issues but is also inter-connected with economic and social factors. Australian society has undergone quite massive changes in ideas over the last 100 years, and will continue to grapple with difficult issues such as globalisation, urbanisation, native title and reconciliation. Community participation in decision making is a growing and welcome reality. It is also an important societal development, as it will take community ownership on a broad scale to solve some of the problems Australia is facing. The key message here is that community attitudes have changed on many issues, and there will be more situations like Lake Victoria where traditional ways of operation are no longer acceptable.

### 4.2 Community consultation

Community consultation is almost a cliché these days – it is a "given". However, this very fact can sometimes lead to underestimating its importance and consequently not achieving effective consultation. The MDBC has invested a lot of effort in developing effective consultation with the community but there have been a few pitfalls along the way from which valuable lessons have emerged.

It is important to recognise that in situations like Lake Victoria, there is often a degree of distrust of government agencies among the various stakeholders. This was certainly the case at Lake Victoria and continues as a constant challenge which is always in the background. Transparency in all interactions with the community is exceptionally important to establish and build trust. Even with this, suspicions can easily develop, depending on the history of the particular situation.

The MDBC and SA Water have invested considerable effort in building trust and facilitating a participatory process with the stakeholders. This included providing information, often of a very technical nature so that the technical issues of water management and environmental consequences could be understood, allowing sufficient time for this information to be considered thoroughly, and involving stakeholders in decisions relating to the protection of cultural heritage and other issues which directly affect them. This was not simply a one way process. Considerable effort was also made to educate technical specialists and government representatives on the nature of the community concerns, in order to help them understand the different perspectives of the various stakeholders.

The stakeholders at Lake Victoria expect to be involved in developing options and selecting the preferred course of action for any strategies to comply with the Consent. This has evolved as a result of a combination of factors including the participatory process described above, the strength of feelings about the competing interests at Lake Victoria and possibly also a general community tendency which has developed over recent years towards increased desire for involvement in issues affecting the community. There have unfortunately, and quite unintentionally, been some occasions where this expectation has not been met, and this has slowed progress on the particular issue considerably. The way through this is to go back to basics: first and foremost, accept that a mistake has been made and then seek the common ground and engage in open dialogue.

These lessons have been learnt through some difficult experiences, but an equally important lesson is that despite all the best efforts, it still may not work. There is a limit to the level of compromise each stakeholder, including the MDBC, is willing to make, and this goes back to the observation that some values are negotiable and some are not. The strength of conviction of the group opposed to covering the burials with water was such that they resigned from the LVAC and have withdrawn from the consultation process. Equally, the MDBC could not agree to operate the Lake to a maximum level of 24.5 metres as this would not guarantee water supply or water quality and had other significant negative impacts on the environment.

### 4.3 Broader issues

Any project is essentially the intersecting point of interest between the project proponent and the various stakeholders. Given the different perspectives a proponent and stakeholders may have of a project, it is hardly surprising that they may view the consultation process, and what they can gain from it, differently. A project proponent tends to view the consultation process as a means to achieve a particular project outcome. On the other hand, each stakeholder group may have a range of issues which are not directly related to the project itself, but which are nevertheless interconnected and important to that group. Stakeholders may see the project as a means to achieve some of the other issues. These things are not mutually exclusive, indeed, there is much to be gained from identifying these issues and working together.

In the case of Lake Victoria, protection of the cultural heritage is the key issue. However, one of the most fundamental concerns for the local Aboriginal community is the lack of employment opportunities. The Lake Victoria project has offered significant opportunities to provide employment in the form of labour to construct the burial protection works and for other tasks related to compliance with the Consent. SA Water employed five workers on a full time basis when the major protection works were being constructed, and continues to employ Aboriginal workers on contract basis whenever there is work relating to cultural heritage. Workers are employed in accordance with an employment protocol which is part of the Plan of Management and provides for Elders from the community to be involved in selecting workers.

This needs to be managed carefully, as even with the best intentions, it can be a double edged sword. As the major construction phase of the project drew to a close in late 1999, it became obvious that there was insufficient work for the workers to continue full time employment. The loss of these five jobs had a significant negative effect on community relations, even though there is an undertaking to employ local Aboriginal workers for any contract work required for protection of cultural heritage or compliance with other aspects of the Consent. This reflects both the importance of this issue to the community, and highlights the sometimes tenuous nature of community relations.

Given factors such as the lack of other employment opportunities, the quite reasonable view that work related to protection of Aboriginal cultural heritage should be conducted by Aboriginal people, and the history of the project, there is an expectation that MDBC and SA Water should be a major provider of ongoing employment for the local Aboriginal community. Clearly this is not always achievable and the MDBC continues to give strong support to other regional employment strategies, in which the NSW Premiers Department has taken the lead.

### 4.4 Inter-agency cooperation

There are at least nine local, State or Commonwealth agencies involved in the Lake Victoria project, all of which have different charters and legislation. Relationships between the agencies have not always been ideal, perhaps due to each agency having an incomplete understanding of the role and responsibilities of other agencies. There has been a noticeable development in the way the various agencies have interacted since the project started in 1994. Some effort was made to educate each other in issues such as water management, and the negotiations involved in revising the Consent conditions provided greater opportunity for open dialogue and increased understanding.

A more co-operative approach has developed, particularly since 1998, which is evidenced in the recent discussions regarding the operating strategy. The

MDBC has been developing the strategy in conjunction with NPWS, but there has also been another layer of co-operation between the NSW agencies to develop a balanced, whole of government approach. At the same time, the strategy is also being considered through the MDBC's consultative processes to ensure the needs of the Governments are considered.

On the ground, it is absolutely necessary for the representatives of these agencies to work together. Each of the four principal agencies (MDBC, SA Water, Department of Land and Water Conservation (DLWC) and NPWS) has a relatively senior representative on the LVAC. Additionally, there is a lot of liaison at the working level and considerable effort to build a cooperative approach.

## 5. FUTURE CHALLENGES

The Consent has required changes to the management of Lake Victoria so that it now heeds the needs of cultural heritage and the environment, as well as meeting the water resource imperatives. This acknowledges the perspectives of the stakeholders and re-establishes Lake Victoria's status as place, coexisting with its importance as a resource. The most immediate challenge is to keep the balance in the routine management issues. This will be a constant challenge, as each decision needs to be made on a case by case basis, viewed on its own merits, but also within the context of the bigger picture, and will depend on the whether the particular value is negotiable or not. The general formula has been set by the experiences of the past few years, but it will require constant attention to ensure that matters stay on track.

The next challenge is responding to new issues which may arise, and which may have values which create another layer of competing interests. One issue that comes readily to mind is the Environmental Flows project. This project is examining a range options to improve environmental flows along the River Murray, and clearly Lake Victoria is viewed as having some potential to enhance environmental benefits in the lower Murray. The development of the operating strategy for Lake Victoria incorporates the need for flexibility to operate Lake Victoria outside of the normal guidelines in exceptional circumstances, and the recent example in October and November 2000 of enhancing flood peaks to South Australia with water stored in Lake Victoria specifically for that purpose is a practical sign that there is a willingness to consider other interests.

The MDBC also recognises that there may be other issues in the future which cannot be foreseen at this stage, hence the need to incorporate flexibility into the operating strategy for Lake Victoria. Therefore, as issues occur, it will be important to use the knowledge gained so far from the Lake Victoria experience, build on the relationships and understanding formed between the stakeholders and use the process developed to seek a resolution.

## 6. CONCLUSION

Lake Victoria can be seen as a victim of the times, a water resource structure created more than seventy years ago under a different set of values, and now having to be justified through the trade-off between the economic value of the water resource and the combination of the social value of Aboriginal cultural heritage and the environmental value of the landscape. It also highlights the issue of who bears the cost of development - that activities undertaken for the public good have a cost which is born by some sector of the community. In the case of Lake Victoria, the activities in question may be either the historical use of Lake Victoria as a water supply, or the actions which have followed the later acknowledgment of the need to protect the cultural heritage and rehabilitate the environment.

The process undertaken since 1994 has been a difficult and frustrating one for all concerned. However, there are two significant up sides. First, a balance has been agreed which allows Lake Victoria to continue operations in its role as a water storage. Secondly, as a result of its efforts to achieve a balance between the competing uses and values of Lake Victoria, the MDBC has learnt much about cooperative processes and community involvement. The lessons can equally be applied to other projects or developments, especially where there is a strong emphasis on community involvement.

## 7. REFERENCES


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# Torrens Lake weir refurbishment

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**Summary**
The Torrens Lake Weir is a heritage listed structure and is an important part of Adelaide's early development as a city, as it keeps a constant water level for recreational and aesthetic purposes within the lake. It is also used for stormwater management purposes by controlling the water levels in the lake during times of flood.

The original Torrens Lake Weir was constructed in 1881 across the River Torrens. The weir had a stepped concrete overflow, 6.1 m high and 40.2 m wide that created the Torrens Lake. In 1929 the central section of the weir was removed and two sluice gates with their associated superstructure were installed to help control the constant build up of sediment upstream of the Torrens Lake Weir. The weir crest level was raised and downstream protection works, including a stilling basin, submerged weir and cribbing structure arrangement were constructed to dissipate energy and stop continuing erosion of the downstream banks during times of discharge.

Due to the deterioration of the structure over time, the weir is in need of upgrading to ensure it safely performs its intended purpose. The objective of the refurbishment is to extend the life of the structure by a minimum of 20 years and ensure technical and operational compliance with current Australian Standards and Guidelines. The proposed design of the structural, electrical and mechanical refurbishment works should preserve and enhance its heritage value and be sympathetic to the structures aesthetics and continued operation.

## 1. INTRODUCTION

In 1998 Hydro Tasmania (through HECEC Australia Pty. Ltd.) was appointed by the City of Adelaide to investigate and undertake a refurbishment of the structural, electrical and mechanical components of the Torrens Lake Weir to ensure that it will adequately and efficiently serve its designed purposes for a further 20 years.

The Torrens Lake Weir is listed on the Register of State Heritage Places and the Register of the City of Adelaide. It has significant local heritage value and is seen as an important part of Adelaide's early development as a city, due to it forming the Torrens Lake, a prominent feature of the city parklands.

There have been three weirs located on or near the present site. The first weir was a small wooden structure built in 1867. It was washed away by floods a few months after construction. The second Torrens Lake Weir was a stepped concrete overflow weir that created the present Torrens Lake. It was constructed in 1881 to facilitate a constant water level for recreational and aesthetic purposes within the lake.

In 1929 the central section of the weir was removed and two sluice gates with their associated superstructure were installed to help control the build up of sediment upstream of the Torrens Lake Weir. At this time the original weir crest level was also raised by 0.61 m and the downstream protection works were constructed.

The downstream protection works consisted of a stilling basin, submerged weir, cribbing structure arrangement and downstream riprap protection. These were used to dissipate energy and stop erosion of the downstream banks during times of discharge. A general arrangement of the existing weir can be found in Figure 1.

The City of Adelaide is committed to preserving the weir's existing appearance and highlighting its heritage value to the city. To preserve the weir's appearance it will be necessary that the design of any refurbishment works be sympathetic to the aesthetics of the existing historical structure.

This paper describes the refurbishment process undertaken by Hydro Tasmania, with emphasis placed on the heritage and hydrological aspects of the refurbishment.

## 2. BACKGROUND

### 2.1 Design

The original concrete Torrens Lake Weir had a stepped overflow 6.1 m high and 40.2 m wide and curved slightly upstream. The original concrete weir was designed and constructed in 1881 by the City of Adelaide Engineer Mr J.H.C. Langdon for the purpose of keeping a constant water level for recreational and aesthetic purposes within the lake and for stormwater management purposes.

Due to the slowing of the water approaching the weir and the amount of silt carried by the River Torrens the area upstream of the weir received large deposits of sediment. This formed substantial silt and mud banks on either side of the river, which extended approximately 1.5 kilometres upstream of the weir.

Operation of the original internal scour valves resulted in only localised scouring of the sediment. The problem persisted and hampered waterborne activities on the lake. Fulltime dredging was undertaken between 1907 and 1929 to alleviate/reduce this silting problem with little success.

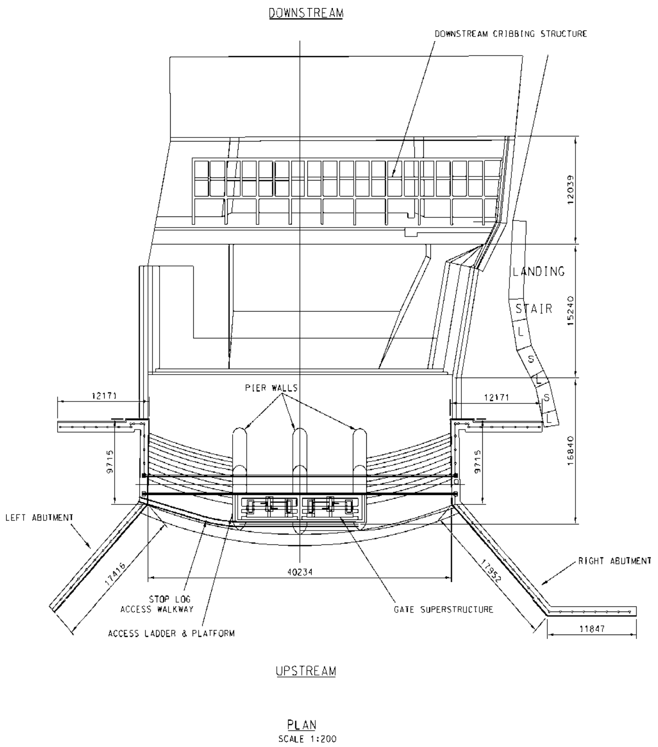


**Figure 1:** Plan of Torrens Lake Weir
(Hydro Tasmania, 2000)

In 1924 the City of Adelaide Engineer Mr R.M. Scott designed two sluice gates and their associated superstructure to help control the build up of sediment.

Due to the complexity of analysing the hydraulic characteristics of the approaches and downstream works a 1/200$^{th}$ scale model of the proposed works was built in 1926. This modeled a range of potential energy dissipating combinations, until a final configuration was decided upon. This was then tested for a range of flow conditions to ensure the energy dissipating modifications were functioning correctly.

### 2.2 Construction

In 1929 construction began with the removal of the central section of the weir. The new sluices consisted of two bays symmetrically situated about the centreline of the weir, each sluice having a clear opening of 6.1m. The gate superstructure is 7.9m high above the 1.83m wide piers and housed two sluice gates 6.9 m high by 6.7 m wide.

The sluice gate design was based upon the Ashford's improved, free roller, Stoney type. The gate lifting mechanism used is a counterweight system in conjunction with hoist motors that raise and lower the gates during operation.

The construction of the downstream protection works consisted of the stilling basin, submerged weir, cribbing structure arrangement, downstream retaining walls and riprap protection. These structures dissipate energy from the fast flowing water discharged from the gates and stop erosion of the downstream banks.

To facilitate annual maintenance on the gates twenty-two wooden stoplogs were used to waterproof the gate area. They were lowered from a railed trolley into the stoplog slots using suitable lifting tackle. The stoplogs were square tallow and karri logs varying in size from 12 inches (lower) to 10 inches (upper).

### 2.3 Heritage

The Torrens Weir and its settings are listed on the Register of State Heritage Places, which signifies it is of cultural significance to the community and should be retained and conserved. The City of Adelaide is aiming to follow these directives in undertaking the proposed refurbishment activities.

To ensure all background information was considered for the refurbishment, local history consultant Patricia Summerling was commissioned to undertake research into the historical nature of the Torrens Lake Weir. Her report gathered information from all known sources about the original weirs, its present configuration and any other relevant issues.

Old photographs, newspaper articles, design and construction reports, contracts, drawings and technical papers were found. This information was collated into the "The Torrens Weir Refurbishment Historical Background" report for use with the project and for the City of Adelaide's future historical reference.

Over the last 75 years minor modifications to the superstructure (mainly due to electrical and mechanical technology advances) and superficial surface deterioration has occurred. Overall the structure has essentially looked the same since construction and is in quite good condition for its age.

To ensure the weir and its surrounds are refurbished to current and acceptable heritage standards, a conservation report were produced by heritage consultant Mark Butcher Architects. The report commented on the cultural significance of the existing weir structure and setting and set out appropriate conservation policies to guide its future conservation and maintenance.

The following issues were highlighted to emphasize the weir's heritage significance;

- The historical integrity of the weir could be maximised via appropriate restoration measures;
- Incompatible or obtrusive elements should be removed;
- The weir's setting (landscaping, paving, lighting, etc) should be optimised to give visual emphasis to the weir and surrounds.

These conservation guidelines were used in conjunction with the investigation findings to produce a refurbishment that satisfies both the heritage and engineering requirements.

To ensure all activities form part of the integrated management approach for the River Torrens the proposed refurbishment activities were also to be consistent with the Torrens Lake and Environs Strategic Plan, which was developed by the City of Adelaide and the Torrens Catchment Water Management Board.

### 2.4 Hydrology

The River Torrens catchment extends from the upper tributaries near Mount Torrens and the eastern ridge of the Mount Lofty Ranges (a few kilometres from Mt Pleasant) onto the Adelaide Plains and to the sea. The total catchment area is approximately 490 $km^2$, and is comprised of approximately 70% rural and 30% urban land use.

The existing Torrens Lake Weir forms a barrier to flow across the River Torrens on the Adelaide Plains near the city centre. It is located approximately 8 kilometres upstream from the outfall at Henley Beach. The river itself is approximately 90 kilometres long and has three dams, the Gumeracha Weir, Kangaroo Creek Dam and Gorge Weir (which is just above the Adelaide Plains) situated on the watercourse. It also feeds two off-channel storages, Millbrook Reservoir and Hope Valley Reservoir.

To ensure the sluice gates were capable of passing a sufficiently large flood their design was based on correlation of discharges between the readings at Gorge Weir and the readings from a gauge at the original weir. For one particular calibration flood, the corresponding flow at the Gorge Weir was 356 $m^3$/s and the estimated total maximum discharge contribution from the local creek network was assumed to be 107 $m^3$/s (approximated). This produced a theoretical maximum flow of 463 $m^3$/s at the Torrens Lake Weir.

However, the actual maximum reading at the weir was approximately 380 $m^3$/s for this flood. The discrepancy in theoretical versus actual discharge is thought to be due to the peak discharges of the small creeks being out of phase with the flood peak of the main river and the saturated run-off conditions of the catchment.

The sluice gates have been designed assuming the flood peaks coincide with each other. From historical data it is assumed that the gates have been designed to pass a flow of 600 $m^3$/s, which corresponds to a water level 1.83 metres (6 ft) above the crest and both gates fully open (20 ft above the sill). The abutment level is 2 m (6.5 ft) above the existing crest.

A check of the recent River Torrens Dambreak and Flood Study suggests that overtopping of the abutments would occur for approximately a 1:200 AEP flood event.

## 3. REFURBISHMENT

### 3.1 Investigations

In order to determine the present condition of the Torrens Lake Weir a structural, mechanical and electrical review was performed on the weir and its associated structures. These included the following investigations:

**Structural Review,** including a condition assessment of the weir superstructure, stilling basin, submerged weir, cribbing and associated structural accessories such as ladders, platforms, handrails etc. The investigations included:

1. Visual inspections;
2. In-water survey by diver;
3. Covermeter survey;
4. Carbonation testing;and
5. Concrete strength testing.

**Mechanical and Electrical Review** of the weir control system involved a:

- **Gates and Valves Review** including:

  **Condition Assessment** of the existing gates, gate mechanisms, sluice valves and pipework.

  **Functional and Reliability Assessment** of the spillway gates, sluice valves, and pipework.

  **Corrosion Protection Assessment** of the weir gates to determine and recommend the preferred corrosion protection system (cathodic protection or otherwise).

- **Control Systems Review** including:

  **Condition Assessment** of the weir controls and control gear enclosures.

  **Functional and Reliability Assessment** of the gate control system.

  **Y2K Reliability** including recommendations as to upgrade options to ensure the weir control equipment is Y2K compatible. A total upgrade of the controller and telemetry system, including a dedicated telecommunication line.

  **Obsolescence Survey** of the controller and telemetry equipment, including an assessment of ongoing maintenance costs with a view to replacing the existing equipment with a system encompassing improvements to security, telemetry, control and reporting.

- **Redundancy Review** of existing electrical accessories, light fittings etc, which are mounted on the weir structure.

- **Lighting Systems Review** - the standard and condition of:

- All night public lighting for the pedestrian/cycle crossing and the surrounding entrance areas to the crossing.
- Security lighting, general floodlighting and maintenance access lighting provided for the weir structure and surrounding areas.
- Heritage style post top lights - their possible restoration and re-use in the same locations or replacement with alternative type light fittings.

These reviews were undertaken and the findings and recommendations can be found in the Preliminary and Detailed Design section of the paper.

### 3.2 Consultation

The Torrens Lake Weir is a high profile structure as it creates the Torrens Lake. Therefore to ensure all relevant issues were raised and stakeholders notified during the course of the project, the City of Adelaide requested the preparation of a stakeholder consultation plan during the early stages of investigations and design.

The plan aimed to ensure that all stakeholders were identified early in the planning processes and that their input regarding issues and concerns were sought. Information regarding the refurbishment was readily available and distributed to all interested parties.

The stakeholder consultation plan was developed after preliminary discussions with council staff and key stakeholders. The plan was considered a live document, and evolved over the project, as more input was received from stakeholders and the design parameters became evident.

The following major groups were considered to be affected by the proposed refurbishment:

- City of Adelaide;
- Lake and Parkland users;
- Restaurants;
- Government Departments (ie Tourism, etc).

### 3.3 Risk Assessment and Life Cycle Study

Once the investigations were complete and the relative condition of the equipment and associated structures was known, a risk assessment study and life cycle analysis was conducted. This report provided an assessment of the risks associated with ownership and operations of the weir and the associated replacement costs.

The risk assessment was carried out using a series of steps, which included:

- Identification of the modes of failure of the weir and associated hazards;
- Assigning a probability to each of the modes of failure or hazard;
- Detailing of the consequences of failure, and
- Determining the risk.

Risks were classified as low, medium or high depending on the scenario analysed and was based on the condition of the existing equipment. Each component was given an overall risk rating and from the analysis the major areas of the weir that are potentially of most concern are:

- The weir stability under flood loading. A preliminary stability analysis indicated the weir may be unstable for floods above approximately the 1:200 AEP event level (more testing is required to confirm). This is potentially unacceptable for a dam located close to a population centre;
- The control system failing due to either the loss of AC power supply, control building flooding, failure of the level monitoring system or control gear. The failure to operate the gates in the correct manner increases the potential for extensive flooding during flood events;
- The gate operation will be severely restricted and risk substantially increased, if regular maintenance on the gates and associated mechanical motors is not performed;
- Potential loss of life from an unexpected opening of the gates. For all but a major flood event, it is preferable to have the gates fail to open rather than open incorrectly;
- Deterioration of the concrete (spalling concrete) and corrosion of steel (sluice valves, chains and chainwheels failure) is a risk to the integrity of the structure and potentially to the public, if left untreated.

The risk assessment findings were used in conjunction with the life cycle study costs to determine the priority of the refurbishment works and the extent of the preliminary design scope of works.

## 4. PRELIMINARY AND DETAILED DESIGN

### 4.1 General

The objective of the project is to refurbish the weir and it's associated structures and equipment to extend the serviceable life of the structure by a minimum of 20 years and ensure that the components satisfy the current Australian Standards and Guidelines. The weir structure is to be kept as near as practicable to its original condition and appearance.
The City of Adelaide is looking to progressively upgrade and rehabilitate the Torrens Lake Weir. The Council will implement the refurbishment over time to manage the risk and funding constraints over their 3 year capital works program.

After researching the historical information, conducting site inspections, diving inspection, performing concrete testing and covermeter surveys, performing a risk and life cycle analysis and the stakeholder consultation the following design recommendations were made to refurbish various components of the weir.

### 4.2 Structural

- Refurbish some areas of the main superstructure. The superstructure is in a fair condition considering its age. However carbonation and chloride ion ingress test results are on the borderline of possible depassivation of the reinforcement;
- Remediate, replace or redesign the downstream cribbing beams. The deterioration of the beams due to water abrasion and the elements has caused concrete to spall and expose reinforcement;
- Repair cracking, patch spalling sections of the surface render and resurface various concrete surfaces with suitable material to ensure the aesthetic appearance of the weir is enhanced;
- Clear the sediment build up in the stilling basin to ensure the hydraulic characteristics of the basin can perform to requirements;
- Replace the maintenance walkway on the upstream face to comply with current safety standards;
- Repair the cracking of upstream nosing of the pier and the turnbuckle bracing;
- Replacement of the footbridge fixing system with a safer bolted system;
- Provide secure ladder access to downstream areas of the weir and remove the southern mesh gate;
- Replace the superstructure access ladder to the deck to comply with current standard AS1657-1992;
- Install fencing on the downstream northern abutment near the retaining wall for safety reasons;
- Consider installing a floating security/oil boom barrier upstream of the weir to capture pollutants and limit access to the structure by lake users.

Currently the detailed design has been completed for the:

- Replacement of the downstream cribbing structure with new reinforced concrete beams and columns;
- Repair and resurfacing of the submerged weir.
- Removal of the sediment from the stilling basin;
- Repair to any deteriorated concrete and resurfacing of the stilling basin floor and sides;
- Provision of protective coatings to stop further deterioration of the concrete and reinforcement.

The main function of the downstream cribbing structure is to dissipate energy during times of high flow and floods and reduce downstream erosion. Over the life of the structure the beams and supporting columns have been subjected to repeated impact loading from debris and the constant erosive nature of the flowing water has caused substantial concrete delamination.

A new duplicate system has been recommended, as it will preserve the heritage aspect of the structure. A cast in-situ or precast beam option has been proposed for construction.

### 4.3 Electrical and Control Systems

This component of the project was undertaken to ensure the Torrens Lake Weir was upgraded with suitable electrical and control technology that was compliant with Y2K requirements and satisfied the current Australian Standards. The following items were recommended for installation:

- Replace the existing gate position metering potentiometer with a multiturn shaft encoder on each gate, which is driven directly from the gearbox shafts thus not using the existing chain drive arrangement;
- Replace the existing 3 limit switches with proximity switch modules mounted within the gate slot to detect the passing of the actual gate body;
- The control system should provide a backup detection of gate position from the gate position transducer and be designed to be immune to switch failure or damage;
- Install hydrostatic pressure and direct float measurement transducers for lake level measurement at different locations around the site. For reliability the signals should both be monitored by an alarmed PLC and compared and checked prior to being used to control the gate opening;
- Install a new screen based PLC control system for each gate. Each gate should be totally independent of the other gate thereby increasing the reliability of having at least one gate operational at all times;
- Power the control and communications system from a 24 V battery and charger system. This non-lethal system will remain fully functional during a mains outage;
- Provide for a permanently installed automatic starting diesel generator;
- Provide a new AC power distribution board fitted with an automatic changeover system to the diesel generator power supplies;
- Remove the old DC lighting systems from the top of the gate structure and restore the old heritage lamp fittings;
- Relocate the large floodlights on the top of the gate structure to highlight the structure's heritage beauty;
- Remove other old unserviceable and visually obtrusive light fittings on the gate structure;.
- Relocate the floodlights for the video security cameras to illuminate only the areas of concern.

The electrical refurbishment of the Torrens Lake Weir was undertaken by GEI Industries in 1999. The contract included the detailed design, procurement, manufacture, factory testing, delivery, installation, pre-commissioning and commissioning of:

- A PLC based control system for each of the two vertical lift gates;
- A new AC power distribution scheme;
- New electric motors on the gate winches;

- Remote control and supervision equipment at the London Rd. depot;
- New functional and architectural flood lighting schemes;
- New transducers for gate position, lake level and the provision for water quality measurement equipment in the future;
- DC battery and charger system;
- Electrical rewiring of the site;
- Provision of miscellaneous equipment and spare parts;
- Alternative Operator panel enhancements to the control system program;
- Training course(s) for Corporation personnel for operation of the system;

### 4.4 Mechanical Systems

The following mechanical refurbishment items were recommended:

- Periodic maintenance schedules for all mechanical items should be undertaken;
- Install cathodic protection to extend the life of the coating that covers the gate, using the sacrificial anode technique;
- The existing gate winch motors should be replaced with three phase motors;
- Fabricate stoplogs to facilitate regular inspection, maintenance and testing of the gates;
- If the stoplogs are fabricated, then the following inspections should be carried out to ascertain the mechanical integrity of the gates and associated equipment;
  - closely check the gate rollers to see if they are in poor operating condition or have heavy corrosion. If so refurbish or replace;
  - inspect the shims used to level the gear support frames. If swelling of the shims or disintegration occurs this could cause misalignment of the drive shaft;
  - ensure the rollers that fully support the gate when lowered can move freely up and down at half the gate speed without jamming.

The objective of the stoplog system is to provide a means to retain the lake water and provide a dry footing from which the sluice gates can be worked on. It provides a means of repairing and maintaining the sluice gates without the need to drain Torrens Lake.

The proposed stoplog system consists of three sections approximately 2.3 m high, 6.9 m wide and of varying weights. They are to be installed and removed by the means of a mobile crane operating from the north side of the weir. Currently the detailed design of the stoplogs has been completed, however as yet no contract has been let for their fabrication and proof installation.

## 5. SUMMARY

The City of Adelaide is undertaking the progressive refurbishment of the electrical, structural and mechanical components of the Torrens Lake Weir, which will ultimately extend the serviceable life of the weir for a minimum of 20 years.

They have ensured that the heritage aspects of the weir are to be preserved and have recommended that if any changes to the fabric of the weir are deemed necessary then they will be minor in appearance. This will allow the unique nature of the weir's appearance and functionality which has been present for the last 75 years to be preserved and enjoyed by future generations.

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# Sustainable management of the Murray-Darling Basin's water resources – A century's progress

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## 1. INTRODUCTION

Natural resources have dynamic quality and quantity trends over time. The term "sustainable management" therefore has little meaning outside of the human context. It specifically refers to management of the whole natural resource, such that inter-generational benefits of the resources to humans and their environment are protected. Put another way: that future generations have at least the same natural resource choices as we have today.

The history of water management in the Murray-Darling Basin since European settlement illustrates the progression towards sustainability of natural resource management in Australia. It is a story that can be told from many perspectives. However, an inescapable theme is that our natural pursuit of use of limited water resources for human welfare and improved economic outcomes has inevitable and undesirable impacts on the environment, both short term and long term. These impacts and our ability to respond to them determine the extent of sustainability that is possible.

The Murray-Darling Basin Initiative which has evolved from a river system compact between governments to a whole of Basin body, illustrates the contribution to sustainability of natural resources that can be achieved by adopting the principles of integrated catchment management.

## 2. MURRAY-DARLING BASIN IN CONTEXT

The Basin covers just over 1 million square kilometres or about 1/7 of the total area of Australia. Average annual rainfall across the Basin varies from over 1000 mm in the south eastern corner to less than 200 mm in the west. The catchment of the River Murray above Albury represents about 1.5% of the total Basin but produced under natural conditions nearly 30% of the mean annual flow of the river to the sea.

The Basin includes 75% of Australia's irrigation development and provides over 40% of Australia's gross value of agricultural production. It provides drinking water for over three million people, contains

30 000 wetlands and represents much of Australia's unique flora and fauna.

However, the Murray Basin represents only a small part of the total surface run-off in Australia. The mean annual run-off in the Murray Basin is almost 23 000 gigalitres, about 5% of the total estimated mean annual run-off in Australia of 440 000 gigalitres.

Of this total run-off, 75% occurs in the eastern and northern basins with nearly two thirds being in the north east and far north basins. In comparison with other countries, run-off in Australia is very low. The USA, which has about the same land mass, produces 4 times the run off and New Zealand, which has only 4% of our land mass, produces about the same total run-off as Australia.

Some idea of the extent of development and consumption of the water resources of the Murray-Darling Basin can be gained from a comparison of the natural flows from the River Murray to the sea compared with average annual flows today. The mean annual natural flow was about 13 600 gigalitres; today it is about 5 200 gigalitres or 39% of natural. Median figures, which remove the impact of the extremes, show that the current day flows are only 21% of natural.

These figures alone would indicate a basin under stress and suggest there are lessons to be learned from the development that has occurred, and the impacts that have arisen.

In essence, water resources of the Murray-Darling Basin are scarce by any measure, and effective management of these resources is crucial to the concept of natural resource sustainability within the Basin.

## 3. WATER MANAGEMENT IN THE BASIN

The Basin spreads over four states and includes the ACT. Fifty percent of its area is in NSW, 25% in Queensland, 12% in Victoria and 6% in South Australia. One of the most critical issues prompting Federation was the respective rights of NSW, Victoria and South Australia to the waters of the River Murray and the possible role of the Commonwealth in resolving the matter. But this was not a matter that could readily be solved by litigation. Each state had and has retained sovereign rights to ownership and management of water.

The creation of Victoria in 1850 left the whole of the watercourse of the River Murray in NSW. In the subsequent half century much experience was gained of drought and flood. By 1902, in the midst of a protracted drought, a conference of government leaders met in Corowa, no doubt confident in the co-operative principles of Federation, and agreed to find a solution to the problem of sharing water between competing states.

The outcome (which took a further 12 years to produce, much debate and a great deal of pragmatism) was the River Murray Waters Agreement between NSW, Victoria, South Australia and the Commonwealth. Its fundamental principles were based on mutual obligations to share available waters, to share the costs of conservation and control works, and to operate within a context of consensus.

The water sharing principles were elegant in their fundamentals. NSW and Victoria would share the waters equally at Albury, would retain the right to develop and use their tributaries, and would jointly commit to providing a minimum quantity of water to South Australia. Costs of development and construction would be shared equally between the states and the Commonwealth; operating and maintenance costs would be shared equally between the states. In addition, except for some specific procedural matters, unanimous decisions would be required.

The governments recognised that, by a compact which was given the force of law in each parliament, they could create a body able to do things that no one of them could achieve independently. Thus commenced the River Murray Commission.

For the next 50 years, the main focus was on development of irrigation and major works of water conservation and control were built along the Murray system. Despite earlier interests, largely from South Australia, to promote navigation for trade along the river, these quickly fell to the pre-eminence of rail. Water sharing, water availability and water quality remained critical objectives.

The Commission operates by co-ordinating the relevant state water conservation authorities in the construction and operation of works. Thus, Hume Dam, Lake Victoria, Yarrawonga Weir and 13 other locks/weirs on the River Murray were constructed. In addition, barrages were constructed at the Murray Mouth and two weirs on the lower Murrumbidgee.

The agreement by the Commission in 1931 to construct the barrages recognised the claims of South Australia that use of River Murray by NSW and Victoria would have significant impact on quality and quantity of water in the lower reaches of the river. After extensive investigation of alternative sites, construction of the present system of barrages commenced in 1935 and was completed in 1940.

Upstream water based development from the River Murray continued to grow, driven by closer settlement objectives and the need on two occasions to meet post war reconstruction objectives.

As development continued, water quality problems emerged. South Australia, which had built the Mannum-Adelaide pipeline in 1949 and the Morgan-Whyalla pipeline in 1955, was experiencing high salinity levels and supply restrictions.

Despite a growing awareness of the inevitable consequences of irrigation induced salt accessions to the river, there was considerable political turmoil over the proposed Chowilla Dam in the late 1960's. It remains a tribute to the joint and co-operative principles of the River Murray Agreement that, in the end, all governments agreed to a more effective alternative – Dartmouth Dam.

The River Murray Water Agreement provided the enduring base for governments to respond to changing circumstances. By the 1970s, it had become evident that the powers of the Commission to manage water quality were almost non-existent. In 1982, the Agreement was amended to allow the Commission to monitor and consider water quality in its activities. It also required the Commission to consider water management objectives including environmental implications. Prior to that time, these matters were entirely state responsibilities.

Within a few years, the Commission had formulated a strategy aimed at controlling salinity in the River. It was broadly based, including salt interception works, increased dilution flows, improved river regulation and improved land management. This objective was expressed in terms of achieving within a decade reduction of salinity levels at Morgan to be less than 800 electro conductivity units (EC) for at least 95% of the time.

## 4. MURRAY-DARLING INITIATIVE

The measures were to be coordinated with concurrent state initiatives. These actions provided the catalyst which led the governments to agree to expand the role of the Commission to the whole of the Basin. In order to reflect the essential commitment of governments to joint action, a Murray Darling Basin Ministerial Council was appointed in 1985. Subsequently in 1988, the role of the Ministerial Council and the creation of the Murray-Darling Basin Commission were ratified by the adoption of the Murray-Darling Basin Agreement.

**The objective of the Agreement was to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Basin.**

An important component of change was the creation of a Community Advisory Committee, independently chaired with regional and special interest representatives and reporting directly to the Ministerial Council. This Committee was first established in 1986 and since then has provided an essential two-way channel of communication between the Council and the Basin Community.

In 1992, Queensland completed the Basin-wide coverage by joining the Commission and Ministerial Council. Subsequently the ACT also became involved.

Inherent to the creation of the Murray-Darling Basin Commission was recognition that water resources could not be effectively managed in isolation from other components of the total natural resource.

The Murray-Darling Basin Initiative had, after almost 70 years, developed into a comprehensive Basin-wide body with a clear charter to promote improved integrated management of the land, water and environmental resources of the Basin.

Whilst it continued its original role in sharing the waters of the River Murray system it now had a broader Basin-wide influence.

This holistic approach to natural resource management is the key to achieving sustainability. It is interesting to reflect on several major water resource issues that the Murray-Darling Basin Commission has been able to address, which it was not able to do through the River Murray Water Agreement.

## 5. SALINITY STRATEGIES

The 1988 Salinity and Drainage Strategy provided a comprehensive framework for joint action by governments and communities. The emphasis was on tackling problems of water logging and salinisation in the Murray irrigation systems and on river salinity in the lower Murray. It included salt interception schemes together with land and water management solutions. The balance that it aimed to achieve was a balance between protection of river water quality and the sustainability of irrigation development. Ten years after it was launched a detailed review confirmed that it had achieved much of its aims. For example, the average salinity in the River Murray at Morgan had been reduced by nearly 60 EC compared with the initial target of 80 EC. Salinities at Morgan were now below 800 EC for about 92% of the time compared with the target of 95%.

However, there was no room for complacency. Studies have shown that without substantial intervention major adverse salinity effects would occur over the next century. The outcomes of a comprehensive salinity audit have been widely exposed over the past year and have provided the basis for recent decisions by governments for a major program of action over the next decade.

A critical element of this approach is the ability to understand and deal with the issue on a Basin-wide scale through the Murray-Darling Basin Initiative. It is a further reflection of the fact that an integrated catchment management approach is fundamental to providing a basis for effective action towards sustainability.

The Ministerial Council has recently adopted a Basin Salinity Management Strategy with emphasis on joint action over the next 15 years. It will guide communities and governments in working together to control salinity and protect key natural resource values within their catchments consistent with the adopted principles of integrated catchment management. It also establishes targets for the river salinity of each tributary valley and the Murray-Darling river system, that reflect the shared responsibility for action both between valley communities and between states. It will provide a stable and accountable framework that, over time, will generate confidence in how we are tracking in our joint efforts to manage salinity.

## 6. LIMITS ON DIVERSIONS

Diversions from the rivers of the Basin have increased progressively over the past century. The scale of growth increased sharply after 1950, with extractions tripling in the 50 years to 1994. This was not sustainable. Indications of rivers in stress were clear. Salinity levels were rising, native fish were in severe decline, wetlands and riverine forests were suffering and toxic algal blooms were occurring. The need for a balance between consumptive and instream uses of water was evident.

In an historic and far reaching decision in 1995, the Ministerial Council decided to introduce a Cap on the diversion of water for the Basin's river system. The dual aim was to:

- protect and enhance the riverine environment, and
- to achieve sustainable consumptive use.

The underlying principle adopted was to cap diversions to the volume that would have been diverted under 1993/94 levels of development.

The impacts already have been profound. The Cap has realistically defined the scarcity and the value of the Basin's water resources.

It is arguably the most significant specific resource management decision taken by the Ministerial Council. Its application is complex and frequently difficult for the states; strong commitment is needed to maintain the purpose. These principles are now enshrined within the Murray-Darling Basin Agreement, which provides for an annual independent audit of compliance across the Basin. This could not have been achieved without the cooperation of the various governments. For example, Victoria and NSW have now voluntarily limited their rights to develop their own tributary diversions in the interests of the River Murray. Again, this illustrates the value of governments working together on a whole of Basin approach with an independent audit each year to provide transparency of compliance.

A recent review of the operation of the Cap has confirmed its value in protecting riverine environments. However, it is by no means clear that the current level of the Cap represents a sustainable level of diversion. To examine this aspect, work is now underway to inform the debate by regular environmental audit of the Basin's rivers; a *Sustainable Rivers Audit*.

## 7. ENVIRONMENTAL FLOWS IN THE RIVER MURRAY AND LOWER DARLING RIVER

Whilst all states are managing water resources in a way that recognises the need to provide water for the environment, it is a specific task of the Commission to develop, with governments, the basis for improved environmental flows for the River Murray and Lower Darling River.

An illustration is the specific allocations made by Victoria and NSW to provide 100 gigalitres per annum for enhancing flows to the Barmah-Millewa forest. This is an example of the need to allocate water for environmental purposes, but it is only the beginning. A major program is now underway to develop options for environmental flows, which will identify environmental benefits, and the means and costs of providing those benefits.

Implementing environmental flows will include modification of current river operations, the development of alternative proposals, and an understanding of their impacts on a Basin wide scale.

A major program to provide fish passage along the river systems is under development. For the River Murray, the Ministerial Council has endorsed the principle of fish passage from the Murray Mouth to Hume Dam at an estimated cost of $10 million over the next five years. A number of these improvements will be progressively installed during on-going structural and safety upgrades of the various structures along the River, including the barrages. A further initiative is the imminent appointment to the Commission staff of a River Murray Environmental Manager.

## 8. WATER TRADING

There is now a highly developed sense of the limits of water availability. This is accompanied by a realisation of the high value of property rights in water.

Each state has encouraged a market in water entitlements, both annual and permanent. This objective is to ensure that water use achieves the highest value.

Temporary trade within states has increased significantly in recent years and is currently around 800 gigalitres per year. Permanent trade within states has now exceeded 100 gigalitres.

Recognising the importance of the interstate market, the Ministerial Council has piloted a project which allows permanent trade across state boundaries in the Mallee region. This market has since 1998 resulted in the trade of about 15 gigalitres of high security water entitlements between diverters in NSW, Victoria and South Australia. Arrangements include adjustment of security levels and adjustment of state allocations. This role is exercised by the Commission.

The extension of the pilot project to the whole of the River Murray system is currently being examined. There are several major issues including maintaining economic, operational, social and environmental impacts. However, there is strong optimism that this essential expansion of trading can be implemented. It will no doubt contribute to improved efficiency and effectiveness of water use. It will also be a major contributor to sustainability of water use.

## 9. SUSTAINABLE MANAGEMENT OF INFRASTRUCTURE

The Commission has responsibility to direct the management of some $1.5 billion of infrastructure which provides states with their shares of water and provides for essential regulation of river flows and protection of water quality.

Much of this infrastructure is more than 70 years old and will require significant renewal investment over the next 25 to 40 years.

The Commission has focused attention on this problem and has introduced measures to manage these works in a business like way. It has created an internal business unit, River Murray Water, to exercise this role. One outcome, consistent with CoAG Water Reform principles, has been to provide a basis for the original equal cost sharing to be revised to reflect the different level of service provided to each state. Since these costs are in the nature of headworks costs and impact on state service prices to water users, there is a need to achieve efficiencies and transparency. This is being achieved and at the same time major programs of renewal and improvement of works is underway. For example, a major structural upgrade of Hume Dam has been largely completed at a total cost of $75 million.

A major objective of the asset management strategies is to achieve sustainability. One element, often not costed in conventional asset management approaches, is the need to treat the river system as a valuable asset. Its use to provide states with shares of water comes at a cost. This needs to be reflected in proper investment in the river system to minimise erosion, loss of vegetation, and other adverse effects. These programs are being progressively developed and included in the costs of service to the states.

## 10. THE FUTURE

Consistent with the origins of the Murray-Darling Basin Commission, the issues outlined above have strong focus on the sustainability of water resources. However, a holistic approach to natural resource management is clearly inherent in any long-term management options for the future.

The Ministerial Council has adopted a Basin Salinity Management Strategy 2001-2015, which sets a precedent for accountable natural resource management in the future.

It has also adopted an Integrated Catchment Management policy for the next decade; a policy which has the overwhelming support of the broad Basin community and governments. It provides a process through which people can develop a vision, agree on shared values and behaviours, make informed decisions and act together to manage the natural resources of their catchment. The decision to manage our natural resources on the basis of catchments reflects the importance of water to the Basin environment, and to the people who live and work within the Basin.

These strategies illustrate the public recognition that natural resource management is central to our future as a nation, and will require a 'whole-of-government' approach that encompasses an unprecedented level of cooperation and commitment within governments as well as between governments.

The institutional structure of the Murray-Darling Basin Initiative is based on those principles of cooperation. Its achievements to date reflect the fact that cooperation between governments facilitates far more effective natural resource management than could be achieved by any one government acting alone.

Present practices and present use of resources is not sustainable. Difficult decisions will need to be made. Such decisions will involve difficult choices. Many of the changes will involve trade-offs between communities and individuals. A sustainable future requires these decisions and the decisions require partnership.

This is well expressed in the recently released statement of commitment by community and governments on future management of the natural resources of the Murray-Darling Basin.

***We the community and governments of the Murray-Darling Basin commit ourselves to do all that needs to be done to manage and use the resources of the Basin in a way that is ecologically sustainable.***

# The history of rainfall collection in South Australia

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**Summary**
From the beginnings of European settlement, South Australia's pattern of development is mirrored in the of rainfall data collection network. Such events as the establishment of the overland telegraph line, the wheat belt expansion and the construction of railways are discernable in the patterns of rainfall measuring sites. In latter years, the decline of rural populations and the amalgamation of primary production land holdings is a probable cause for a thinning in the more remote rural network. The diligence and persistence of the people of this largely volunteer data collection network is becoming increasingly appreciated with every passing year. The addressing of such problems as climate change and its effects on agriculture and water resources, decreased profit margins and increased capital investment in all types of projects requires access to accurate and reliable environmental data inputs. Australia's climate database and particularly the rainfall component, is proving to be an extremely valuable resource. Some recent changes and future directions for data collection and archival are indicated.

## 1. THE EARLIEST RECORDS

Colonel William Light (1786-1839) was appointed Surveyor general fro the new colony of South Australia and arrived at Kangaroo Island in August 1836. Most of Light's journals, diaries, letters, sketches and paintings were unfortunately lost in January 1839, when his surveyors hut near the corner of West Terrace and North Terrace was accidentally burned down. They, no doubt, would have contained considerable weather information for the 1837-38 period. Soon afterwards, Light's health deteriorated and he died of tuberculosis in 5 October 1839, aged 53.

Light's deputy, George Strickland Kingston (1808-?) took rain gauge readings at his town acre residence at the corner of Grote Street and West Terrace, Adelaide from 1839 till 1878. Dr William Wyatt, a Protector of Aborigines, compiled temperature observations for Adelaide taken at 9am, 3 pm and 9pm for the period November 1840 to October 1841. The two gentlemen co-operated with WJ Power, who incorporated the above data in his *Climate of South Australia* article in the 1842 Royal South Australian Almanac (Gentili, 1967).

Gentili (1967) states at the Surveyor-General's Office temperature observations were made at 10,12, 14 and 16 hours from April 1844 to March 1845.

## 2. THE ADELAIDE OBSERVATORY AND THE WORK OF SIR CHARLES TODD.

On 10 February 1855, the colonial government of South Australia appointed the Londoner, Charles Todd, (1826-1910) to the dual post of Superintendent of Telegraphs and Government Astronomer. He was to set up, direct and supply weather services to South Australians for the next half a century to 1906, when he retired.

Todd was a leading exponent of the science of Meteorology in Australia (Gentili, 1967). When he arrived in South Australia on 4 November 1855 Todd immediately commenced meteorological observations, initially at his private house in North Adelaide, then at Government House grounds on North Terrace and finally, on completion in 1860, of the Adelaide

**Figure 1:** Sir Charles Todd

Observatory, at West Terrace. (Corbett and Robertson, 1972). The Observatory was some 400 metres north of Kingston's site on the corner of West Terrace and Grote Street.

Todd, as an astronomer and electrical engineer, was an enthusiast of the telegraph, which had been invented by Samuel Morse in the late 1830s. Todd was a visionary and he would assert that the telegraph was "to the meteorologist what the telescope is to the astronomer" (Todd, 1894). Recognising that the telegraph provided a quick mean for gathering weather observations, that could systematically be used to get a broad synoptic view of the prevailing weather over a considerable area, Todd, in 1856 submitted a meteorological plan to the government.

The plan depended on a network of observations that was required to report daily by telegraph to the central observatory. Growth was slow at first, but as the telegraph network grew, so did his weather-reporting network. The expansion got a greater impetus in 1870 when Todd was also made Post Master General and all post offices came under his control.

As Post Master General, Todd set about constructing the famous Adelaide to Darwin overland telegraph linking Australia with Europe through Batavia (now Djakarta). This "building of a nation" project was completed in November 1872. The project had taken 18 months to complete. It covered a distance of 3 000 km along 36 000 poles through much of the land that had been explored by Macdouall Stuart (1816-1866) in the second half of 1862. By 1877, Todd had extended the Telegraph from Port Augusta to Eucla, on the West Australian border that, in 1861, had been extended from longitude 132°E to 129°E.

Todd trained his own observers and interested volunteers. He instructed his Post Office staff to take regular daily observations and to post same to the Adelaide Observatory. He systematically collected information from South Australia and the Northern Territory and arranged for the interchange of data from other Australian colonies and New Zealand, which had all embraced his meteorological system.

Todd pioneered the production of weather maps and from 1882 onwards they were being regularly produced and published in the local and interstate newspapers. Todd published journals, presented papers to scientific organisations and submitted annual reports to the State Government. He held leading positions in a number of learned societies, education and public institutions and was always ready to assist and advise.

In addressing the 5th conference of the Australasian Association for the Advancement of Science, held in Adelaide in September 1893, Todd claimed that there were at the time 21 meteorological stations throughout South Australia and the Northern Territory with 370 rain gauges. The network for Australian and New Zealand had a total of 357 stations with 2 575 rain gauges (Todd 1894).

**3. GOYDER'S LINE**

George Woodroffe Goyder (1826-1898) arrived in South Australia in 1851 and was initially appointed to the Colonial Engineers Office. In 1861, Goyder was made Surveyor General. In late 1865, at the height of a severe drought, he was given the task of assessing its extent. Goyder made several trips to the north of the state, making notes as to the type of vegetation and condition of the soils. He finally defined a line on a map (Figure 2), to the south of which rainfall was deemed to be reliable. The government then opened up for development agricultural land south of Goyder's line within a system of counties and hundreds.

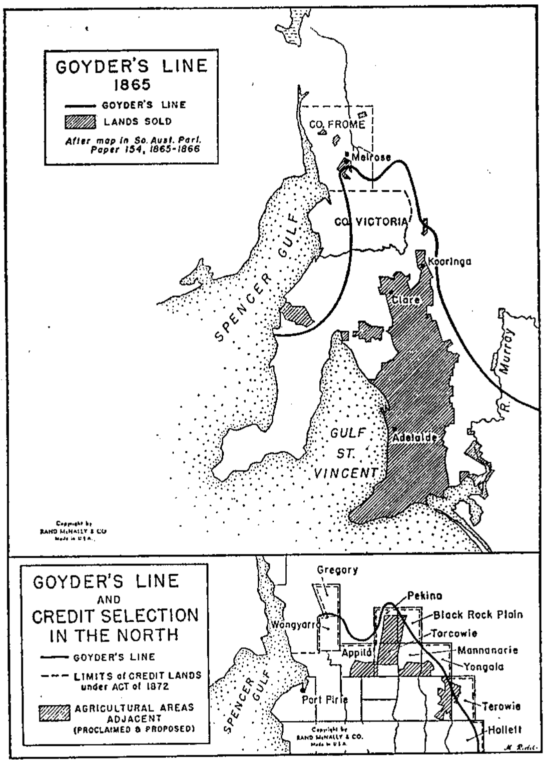


**Figure 2:** Goyder's Line (from Meinig, 1963)

During the favourable years of the early 1870s, pressure mounted for the restriction imposed by Goyder's line to be removed, arguing that it was unnecessary and that the climate was becoming more favourable for agriculture in the northern interior of the state. In November 1874, the government amended the *Waste Lands Amendment Act* thereby releasing all of the land up to the 26th parallel. By the early 1800s, a series of droughts (or perhaps a return to more normal conditions) saw farmers suffer terrible losses and many settlements north of Goyder's Line were abandoned.

**4. CLEMENT WRAGGE**

One of Australia most colourful eccentrics, the meteorologist Clement Wragge (1852-1922), was appointed to the South Australian Survey-General Department in 1876 where he was presumably associated with Todd.

While in South Australia, Wragge visited many inland centres where, noting the bareness of the land, he suggested that the waters of the east coast rivers be diverted over the ranges and collect in a great inland sea in Central Australia. Wragge had foreseen the Snowy Mountain Scheme. When no politician would listen to his scheme he returned to England in 1878 and devoting himself to meteorology he set up the Ben Nevis Observatory in 1881 to study the variations of weather with altitude.

While in England he married and in 1884 he returned to Adelaide to set up the Mount Lofty Observatory.

After some time in Tasmania, where he reorganised the Tasmanian meteorological network, he was appointed Government Meteorologist for Queensland and in 1887 moved to Brisbane.

## 5. GATHERING OF DATA AT WEST TERRACE AND SOUTH AUSTRALIA

Three sites were associated with the Adelaide -West Terrace observations (observation station number 023000) these are all within 400 metres of each other and were:

Kingston's Town Acre at the corner of Grote Street and West Terrace, where George Kingston took rainfall observations from 1839 to 1879;
The Observatory Site - established by Charles Todd in 1860;
The Bureau Site- this was the Commonwealth Bureau of Meteorology built in 1940 at the corner of Glover Avenue and West Terrace. Additions were made in 1962-63. Demolished about 1980.

For 19 years, until 1879, both Kingston's and the Observatory gauges were run concurrently, the mean annual difference in that period being only 6.5mm, with Kingston's figures being the greater (Corbett and Robertson, 1972).

In 1979, observations ceased at West Terrace, ending 139 years of record in that area.

The Bureau commenced rainfall observations at its new Regional Office site at Kent Town in February 1977,allowing an overlap period of two years with the West Terrace site.

## 6. METEOROLOGY IN SOUTH AUSTRALIA SINCE FEDERATION

Prior to Federation, each of the Australian colonies had their own meteorological office. All colonial meteorologists had additional functions other than observing the weather. In fact, most served as Government Astronomers and Todd was, in addition, Post Master General of South Australia.

Australian colonial Government Meteorologists in fact pre-empted federation. Realising that the weather recognises no political boundaries, they held an inaugural congress in Sydney in 1879 for the purpose of fostering uniformity in the science and exchanging mutually desirable information. The Sydney congress was in turn followed by two others held in Melbourne in 1881 and 1888. Todd eminently gave a lucid summary of the status of meteorology in Australia and New Zealand in his 1893 address in Adelaide to the 5$^{th}$ meeting of the Australasian Association for the Advancement of Science (Todd 1894).

Australian meteorologists were pre-eminent overseas. Todd attended the 1885 International Telegraphic Conference in Berlin while both Clement Wragge and Georg von Neumayer, the Victorian Government Meteorologist, attended the 1891 Munich International Meteorological Congress in Germany.

Following Federation (1 January 1901), meteorology became the responsibility of the Commonwealth (Meteorology Act) and the Commonwealth Bureau of Meteorology was created as a part of the Department of the Interior in 1907. It was at this time that meteorology in Australia formally separated from astronomy. Wragge had argued for years for a Federal Bureau of Meteorology, separate of astronomical duties. (Gibbs, 1998).

HA Hunt was appointed first Commonwealth Meteorologist in 1907 and work commenced at the Bureau on 1 January 1908. However, Bureau staff continued to occupy a part of the old Observatory until 1940, when they moved to an adjacent site on West Terrace on the corner of Glover Avenue. The elegant Observatory was demolished in 1962 to cater for extensions to Adelaide Boys High School.

At the time of Todd's retirement in December 1906, there were 257 operating rainfall stations in South Australia, 17 of which were fully equipped for all meteorological observations. The fully equipped stations that furnished daily reports to the Adelaide Observatory were:

> William Creek, Farina, Port Augusta, Yongala, Clare, Kapunda, Belair, Stirling West, Mount Barker, Mount Gambier, Eucla (WA), Fowlers Bay, Streaky Bay, Port Lincoln, Cape Borda, Robe and Cape Northumberland.

During the last 30 years of the 19$^{th}$ century and the first 20 years of the 20th century, there was steady growth of the rainfall collection network. Many of the extensions into the north and northwest of the state followed the construction of the Oodnadatta (1891), Perth (1917) and Alice Springs (1918) railway lines.

In recent years, a gradual thinning out of the network in the northern half of the State is noticeable and is

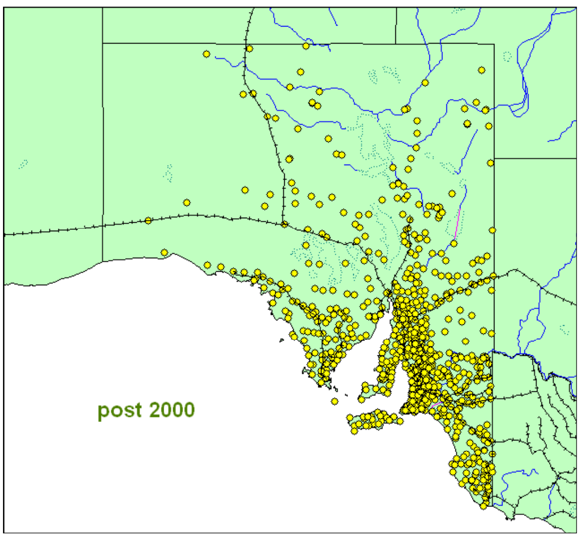


**Figure 3:** The rainfall data network in South Australia 2001

mainly due to property amalgamations and a general decline in the rural population.

Currently the Bureau operates a network of 790 rainfall stations in South Australia (Figure 3), of which 93 measure additional parameters such as temperature. Fifty of these use Automatic Weather Stations, some with additional manual input at some hours of the day. Six sites are Bureau staffed stations, all but the Kent Town Office performing a full program of surface and upper atmosphere measurements.

These network statistics represent approximately 10% of the national total, a value which has remained relatively constant for many years.

## 7. RAINFALL INTENSITY

Until relatively recently, rainfall intensity data was collected using the Dines siphoning pluviograph. (Figure 4). These instruments were very expensive to purchase and were quite unreliable, requiring constant maintenance. An additional problem was the very labour intensive data analysis required to extract information from the charts.

A recent development in instrumentation is the widespread installation of data loggers on all tipping bucket rain gauges in South Australia. There are now 70 such equipped sites in South Australia. The data logs are event driven and are usually collected every 3 or 6 months or on a needs basis. The data is archived in a database and may be extracted for periods ranging down to 6 minutes.

Although there have been some problems with the reliability of the tipping bucket instrument, this is now being rectified and regular calibration checks are carried out.

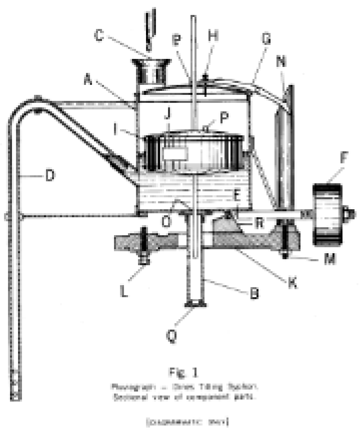


**Figure 4:** Dines siphoning pluviograph

## 8. FLOODS

The Bureau operates an "ALERT" system, which consists of rainfall, and stream gauges located in the Torrens, Onkaparinga, Gawler, Brown Hill Creek and Hutt River catchments. These are linked by radiotelephony to base stations at local councils, emergency service units and the Bureau. When certain threshold values are exceeded, clients are notified automatically. The availability of these data together with those from the automatic weather stations network in near real time has now enabled their display on the Bureau's web site (Figure 5).

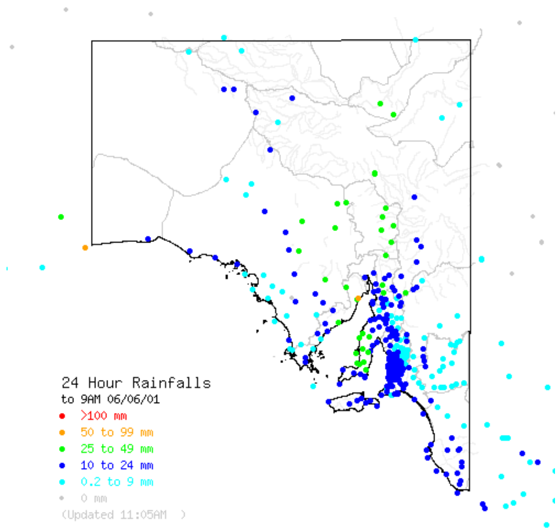


**Figure 5:** Example of real-time rainfall data on the web

## 9. LONG TERM RECORDS

South Australia has some of the longest continuous rainfall records in Australia. With the West Terrace sites in Adelaide totalling 138 years of records between 1839 and 1976. Outside of Adelaide, the first stations to begin rainfall observations were Burra (1859), Mount Gambier, Robe, Port Augusta and Bungaree (1860), Gawler, Kapunda, Mount Barker, Strathalbyn, Penola, Goolwa, Warooka and Bridgewater (1861) and Clare and Willunga (1862). Most of these sites are still operational.

These long records are obviously extremely valuable for the detection of climate change. It must be said however that there is very little evidence of any trend over southern South Australia. A recent example of the completion of 100 years of continuous record from Ardrossan (Winulta) shows no discernable long-term trend, but certainly periods of significant variation from the mean.

Long term rainfall records are also used as baseline, or

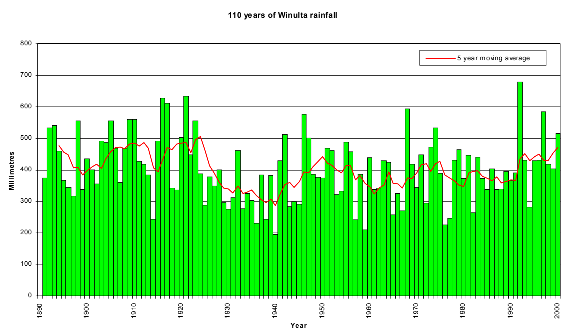


**Figure 6:** 100 years of rainfall at Winulta (22021)

input data, for climate models. Studies published recently by CSIRO use these data combined with projections about changes to the chemistry of the atmosphere to make forecasts of changes to temperature and rainfall in Australia. The forecasts indicate a drying trend in southern South Australia both at 2030 (0% –10% drier) and at 2070 (10% – 20%), (CSIRO, 2001).

In future years, much more use is likely to be made of remote sensing, both from the ground and by satellite. Satellite imagery is already being used to automatically delineate cloud free areas where there was no possibility of rain. This may seem a trivial exercise but it is often difficult to determine if the non-receipt of an observation is an indication of no rain, or is indeed a missed observation. Of course, there are still large areas of Australia from which no ground-based data is received.

These techniques are being incorporated into processes that automatically analyse and map Australia's rainfall data in near real time. Analyses of total rainfall for one day, one week, month to date, previous month, three, six and twelve months, together with decile ranges, departure from normal and drought index are now available from the Bureau's web site (Bureau of Meteorology, 2001) on the afternoon of the observations (Figure 7).

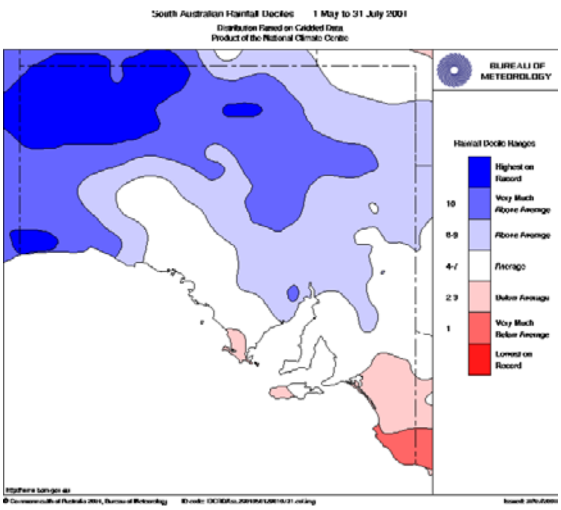


**Figure 7:** Typical three monthly decile map

Research continues into the relationship between radar observations and rainfall amount. Although it is well known that the intensity of Radar echoes is roughly proportional to the rainfall intensity, attempts to quantify the relationship are still continuing.

There are many factors which introduce elements of uncertainty. These include: -
ice and water droplets of different sizes reflect differently;
the signal is attenuated as it passes through a rain area;
the curvature of the earth changes the height of observation with distance.

However, with the electronic and computing technology now available it is theoretically possible to quantitatively monitor the amount of rainfall over an area. Figure 7 shows the present radar coverage over Australia. Output from these radars is available in real time on the Bureau's web site.

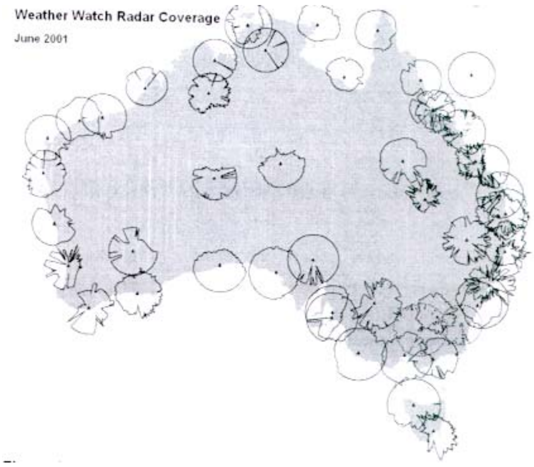


**Figure 8:** Weather radar coverage in Australia

**10. CONCLUSION**

At first glance, the reading, collection and archival of rainfall data seems almost a trivial task. But as we have seen from looking briefly at the history, current state, and future directions of this pursuit, an interesting and complex activity is revealed.

Modern technology now allows the collection, analysis and display of more data than ever and in a much more timely manner. Remote sensing methods offer even greater scope. There is no doubt that these data will be used for more and more innovative purposes in future years.

The value of our climate database as a resource for future planning is incalculable.

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# Stormwater in Adelaide, South Australia - from SWS to WSUD, 'myths' and realities

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**Summary**
The provision of stormwater infrastructure has been the responsibility of Local Government since the early days of settlement. In recent decades the State Government has assisted Local Government in this provision, initially through legislated schemes and subsequently through a direct subsidy arrangement. While this assistance has allowed much of Adelaide to be provided with adequate trunk drainage systems, this provision is by no means complete. Over the last decade or so stormwater management has broadened to include other objectives. New institutional arrangements have been put in place to meet those objectives. With these new objectives, some 'myths' also seem to have arisen regarding stormwater in Adelaide. With the current trend to inner city living and increased pressures for urban redevelopment these 'myths' need to be balanced against reality if we are to have proper policy formulation, planning and funding for the future.

## 1. INTRODUCTION

In recent years the catchcry that *stormwater is a resource* has come to prominence. This is set in contrast to the supposedly earlier catchcry that *stormwater is a nuisance to be got rid of as quickly as possible.* Both sum up seemingly irreconcilable views of how stormwater should be managed. Yet both views are equally valid in certain situations. There is no doubt that the potential resource value of stormwater has been overlooked in the past. Equally there are situations where stormwater is not only a nuisance but can be downright dangerous.

By outlining the history of stormwater management in Adelaide, from prior to the South-Western Suburbs Drainage Scheme (SWS) through to the current ideas of water sensitive urban design (WSUD) I hope to place both of these catchcries in a more balanced perspective and try and dispel some of the current 'myths' about stormwater in Adelaide.

## 2. IN THE BEGINNING

Stormwater drainage in this state has always been considered to be the preserve of Local Government. It is not clear how this responsibility originated but one can imagine that with a favourable climate and a relatively low density of development there was seen to be no need for extensive drainage systems. What was needed was seen to be essentially local in character and so could be safely left to the relevant local council.

The development pattern of Adelaide up until the Second World War supports this notion. Examination of the first topographic map of Adelaide, prepared by the Australian Section Imperial General Staff and printed in August 1939, at that classic imperial scale of 1: 63 360, shows the then limited development in Adelaide. Most of Adelaide's urban development had taken place on the higher ground surrounding the parklands. The only exceptions were the transport corridor to Port Adelaide and the beachside suburbs of Grange, Henley, Glenelg and Brighton. The lower lying areas to the west and south west of the city were notably absent of development, probably due to poor drainage.

However the runoff being generated by the then established inner suburbs coupled with the natural runoff from the Adelaide Hills must have already been causing sufficient problems for the State Government to become involved with the passing of the *Metropolitan Drainage Act* in 1935.

Despite the all encompassing title, the Metropolitan Drainage Act was actually quite limited in scope. It is described as *an Act to authorize* (sic) *the construction of works for the drainage of land periodically flooded by the River Torrens, the River Sturt, and the Keswick and Brownhill Creeks, and for other purposes.* This is the Act that resulted in the construction of the Torrens Outlet channel and the concrete lining of the lower reaches of the Keswick and Brownhill Creeks that exist today. Parts of the River Sturt were also concrete lined but that work was later superseded by the current concrete lining.

Given the nature of the work, the Act could have been more aptly described as *an Act to authorize the construction of works for the* ***protection*** *of land periodically flooded…………* Also of interest is to speculate what was the then driving force behind the enactment of this Act. Given the then sparse population west of South Road, the protection of urban development couldn't have been a prime consideration. More likely, given the rural bias of the day, the protection of the then semi rural landholdings was probably a greater consideration. Whatever the reason, this Act resulted in the construction of works that gave some measure of protection from flooding of land on which part of the great post war housing boom was to follow. The Act was also essentially reactive in that it was a response to something that was already occurring.

## 3. SOUTH WESTERN SUBURBS

While urban development could expand to north and north east with relative impunity, the lower lying western and south western suburbs presented a greater challenge. The availability of the River Torrens and Keswick and Brownhill Creeks, as outfalls, coupled with the Metropolitan Drainage Act flood protection works ensured that there were less drainage problems west of the city than in the south west suburbs. A large chunk of land being left in a semi rural condition in the form of the Adelaide Airport also helped.

In the south west suburbs things were not so promising. The River Sturt meandered across the plain with limited capacity, fed by a rural catchment second only (for the then metropolitan area) to the River Torrens in size. Further the Eden escarpment closed in, giving rise to a number of minor escarpment creeks that looked prone to flash flooding.

Place on this area rapid urban development with no concurrent provision of drainage infrastructure and the end result was a major stormwater drainage and flooding problem. As someone who grew up in the south west suburbs, I well remember the frequent street flooding that occurred and those unfortunate residents whose housing was lower than most and who suffered the occasional house inundation.

I also recall the River Sturt at the time. Unlike the lost Arcadia that the modern day critics of the River Sturt concrete lining like to conjure up, I recall a degraded, eroding watercourse that was a dumping ground for rubbish and home for pest flora and fauna.

The State Government response to this situation was again another Act of Parliament (South–Western Suburbs Drainage Act 1959) under which a series of trunk drains feeding both into the River Sturt and direct to the sea were constructed. Also constructed was the River Sturt concrete lining to increase the capacity of the channel, the River Sturt Flood Control Dam to limit the inflows from the rural area and enhancements to the Patawalonga Basin and flood gates to ensure safe passage of floodwaters to the sea.

The South-Western Suburbs Drainage Scheme differed from the pre war Metropolitan Drainage Act in that it was about protecting existing urban development. This was reflected in the preamble - *an Act to authorize* (sic*) the construction and operation of works for the* ***prevention*** *and control of flooding in the South-Western* ***Suburbs*** *of the Metropolitan Area…..* (my emphasis).

I can also assure you that in that sense the South-Western Suburbs Drainage Act was extremely successful. The south western suburbs were left with a legacy of a network of properly designed trunk drains and outfall system to the sea. As the system was largely designed by the then Highways and Local Government Department it also left a legacy of expertise in stormwater matters at the State Government level that exists to this day.

Of technical interest the scheme was designed using design rainfalls specifically derived from analysis of the Adelaide pluviograph record and it would have been one of the first to be designed using the "Missouri Charts" for estimating pressure losses through junction boxes etc.

However like the pre war Metropolitan Drainage Act, the South-Western Suburbs Drainage Act was in response to a situation that had developed. Urban development was generating stormwater and in large quantities. It certainly wasn't considered to be a resource, instead it was causing economic loss and human suffering. It was being generated by urban development that had few controls placed upon it (the first really effective planning and development legislation was not enacted until 1966). The developers themselves were not interested in trying anything different as demand was outstripping supply and they had no responsibility for the consequences of their development.

So, not dissimilar to other government infrastructure provision, stormwater infrastructure provision quickly became a "catchup" game, responding largely to problems that were a consequence of past decisions. In such an environment, the provision of single purpose infrastructure that disposed of all stormwater from the minor flows right up to and beyond the design event was often the only option left.

## 4. STORMWATER SUBSIDY SCHEME

The obvious success of the South-Western Suburbs Drainage Scheme led to pressure on the Government to implement similar arrangements in other parts of the metropolitan area. However, only one further scheme along similar legislative lines was set up (Metropolitan Area (Woodville, Henley and Grange) Drainage Act, 1964). After that, with a newly elected Labor Government in power other alternatives were considered. As the State Government was providing all the funding up front, with half to be repaid (at concessional interest rates) over 53 years by the Councils concerned, the alternative of a central authority to implement a centrally planned drainage scheme for the entire metropolitan area looked attractive.

This concept even got as far as the drafting of a bill to set up such an authority. The contents of this draft must have frightened influential people in Local Government as an adverse backlash to the idea of a central authority developed and the proposal was dropped. Instead of returning to legislated schemes and the provision of all the funding up front, the Government chose a different solution.

The decision was made to leave the provision of stormwater infrastructure squarely the responsibility of Local Government. State Government assistance would be in the form of a dollar for dollar subsidy for major stormwater drainage works. So in 1967, a non-statutory administrative arrangement named the State Government Stormwater Drainage Subsidy Scheme came into being. Technical and financial administration was to be the responsibility of the Highways and Local Government Department, utilising the same expertise that had been gained with the design and implementation of the South-Western Suburbs Drainage Scheme.

The Adelaide metropolitan councils jumped at the chance and some other longstanding drainage and flooding problems soon begun to be addressed. Some of the more notable projects from the earlier years were:

- Flood Mitigation / Capacity improvement works on sections of Second and Third Creeks;
- Major stormwater pumping stations at Port Adelaide;
- Provision of trunk drainage in the north west suburbs;
- Provision of trunk drainage in the rapidly expanding Salisbury area following urban development.

Most of this early work was aimed at providing or upgrading trunk drainage systems to an adequate standard and to prevent flooding in the worst affected areas. Again virtually all of this work was in 'catchup' mode with little scope to do other than remove all of the stormwater through the provision of single purpose stormwater infrastructure.

Despite expansion of the Scheme over the years (country areas / flood mitigation 1970s, wider stormwater management objectives 1990s) assistance in the provision of trunk drainage infrastructure in Adelaide has remained a core business of the Scheme. However, despite over 30 years of work, there still remains a surprising large area of Adelaide that lacks an adequate trunk drainage system, either in areal extent, in standard or both. Evidence of this can be seen in the frequent minor flooding that occurs in areas as diverse as Birkenhead, Seaton, Cowandilla and Parkside, through to the more major problems on the Glen Osmond and Keswick Creeks.

The long-term availability of funding from the Subsidy Scheme gradually encouraged a more proactive approach to solving current and avoiding future problems. Studies were encouraged that identified not only current problems but also on areas that were likely to be sites for future urban development and so allow planning to avoid future problems. The various City of Munno Para Drainage Strategy Master Plans are a good example of this type of approach. Such studies allowed stormwater infrastructure planning to get 'ahead of the game'. Getting ahead of the game also allowed the reservation of sufficient land so that other more environmentally friendly drainage features such as open swales and detention basins could be more widely adopted.

Of recent times the Subsidy Scheme, under new Ministerial responsibilities and in its new broader role as the Catchment Management Subsidy Scheme has fallen on hard times, following a severe funding cut in favour of other government priorities.

While this funding arrangement has now been in existence for more than 30 years, mere longevity in itself, is hardly a reason to dispense with it. As described above the provision of adequate trunk drainage systems is far from complete. While adequate planning and new ideas can now allow more of a 'stormwater is a resource' approach in newly developing areas, there are still large tracts of older development which lack an adequate trunk drainage network. It is these areas where stormwater is still a nuisance and potential hazard and where removal from the area is still the only viable option. The Subsidy Scheme still represents a valuable source of assistance to Local Government in this regard.

These days however, even from older areas (with a bit of luck), stormwater can be drained to a regional wetland, where the quality can improve prior to discharge to the sea. With even more luck stormwater can end up in an aquifer via an aquifer storage and recovery (ASR) scheme to allow recovery for later use.

## 5. BEYOND DRAINAGE AND FLOODS

While there were earlier advocates and suggestions of the water resource potential of urban stormwater (eg Read, 1978) the landmark publication in this regard must be the Urban Stormwater - A Resource for Adelaide report (Fisher and Clark, 1989). This report not only more widely publicised the issue for the first time, it also made an estimate of the resource available that has been widely quoted since. It also turned the then E&WS Department's interest towards urban gauging for the first time and perhaps most significantly set in train a long process that ultimately led to the setting up of Catchment Water Management Boards.

Stops along the way included the Metropolitan Adelaide Stormwater – Options for Management report (Environmental Consulting Australia, 1991) and the Stormwater Management Arrangements for Metropolitan Adelaide report (Joint State and Local Government Task Group, 1993).

Along the way the debate was widened into what was termed multi-objective stormwater management. In particular the 1991 Options for Management report, which was commissioned by the E&WS Department, gave consideration to:

- improved stormwater quality;

- greater beneficial use of stormwater;
- adequate flood control;
- environmental protection;
- improved urban amenity.

In my view some of the assumptions of how Adelaide's stormwater was being managed, at the time this report was commissioned, were already dated. For example the first stage of the Greenfields Wetlands and the Fourth Creek flood mitigation works had been constructed with Subsidy Scheme assistance well beforehand. Both were excellent examples of addressing most of the points listed above. Both were made possible by having adequate land available. Nevertheless the report proved to be a starting point for institutional change in stormwater management in Adelaide.

The report also listed some first order estimated costs for a stormwater management program in Adelaide, which are worth repeating here.

**Table 1**: Stormwater Management Program (1991 $million/annum)

| Component | Over 20 years | Over 30 years | Over 50 years |
|---|---|---|---|
| **Flood Control** | | | |
| Trunk Drainage | 13.2 | 9.6 | 6.6 |
| Street Drainage | 19.8 | 13.8 | 9.0 |
| **Water Quality** | | | |
| Marine Environment | 3.5 | 2.4 | 1.5 |
| Recreational Water Bodies | 2.0 | 1.4 | 1.0 |
| **Water Resources** | | | |
| Groundwater Recharge | 1.8 | 1.3 | 1.0 |
| Mains Water Substitution | 1.8 | 1.3 | 1.0 |
| | | | |
| Catchment Management Program | 7.0 | 6.0 | 5.0 |

While the street drainage figure was criticised at the time as being too high, the other figures were considered to be more realistic. More importantly the estimates serve to illustrate the relative amount of effort required on the various aspects of a broader stormwater management program. These proportions were considered reasonable estimates at the time and today still seem to be realistic.

Of course, in the 10 years since this report was released, expenditure at these sorts of levels has not been achieved. However, new institutional arrangements (Catchment Water Management Boards) have been set in place to address and fund the water quality, catchment management and water resource aspects of stormwater management.

Meanwhile flood control has remained the responsibility of Local Government with continuing support from a revamped Subsidy Scheme. However, with the apparent success of works from earlier times, the perceived urban flood threat in Adelaide has receded and with it so has the level of State Government financial support through the Subsidy Scheme. Firstly by widening the eligibility criteria of the Subsidy Scheme, without any commensurate increase in funding, and secondly by the more recent direct funding cuts to the Scheme.

## 6. WATER SENSITIVE URBAN DESIGN

Water Sensitive Urban Design (WSUD) is a response to the realisation that urban development produces a large water demand that is met by importing large volumes of treated water from elsewhere, often across large distances, at considerable cost. At the same time large volumes of stormwater from roofs are discharged unused from urban developments via expensive stormwater systems (Coombes et al, 2000).

Application of the principles of water sensitive urban design can range from simply adopting an open channel / swale strategy, where runoff provides a source of water for landscaping etc through to totally integrated developments where all wastewater (including stormwater) is collected and treated to appropriate levels and reticulated around the development for various non-potable uses. Properly designed, such integrated developments can approach self-sufficiency in water supply and use.

Examples in Adelaide include Oakden, where a landscaped detention/retention basin provides a source of water for an ASR system. Water is later recovered for irrigation of the landscaped reserves during the summer months of the year. The basin also limits peak flows to the capacity of the downstream infrastructure. A much more integrated development is now being developed at Mawson Lakes, which also takes advantage of the supply of water from Dry Creek (upstream urban runoff) to incorporate larger scale water features on the site.

WSUD in greenfields projects offers the most potential for a reduction in size or demand for downstream stormwater infrastructure. This advantage has been one of the driving forces behind the adoption of WSUD in Adelaide to date. While there are several examples of smaller scale WSUD based development and various other ideas for individual on-site retention such as soakage pits, 'rainsaver' gutters and larger rainwater tanks, the adoption of WSUD in developed areas is in my view much more problematic.

To provide guidance in this area the Patawalonga and Torrens Catchment Water Management Boards in cooperation with Planning SA have recently published a draft 'Guidelines for Urban Stormwater Management' manual (Planning SA, 2001). This publication recognises the problems of developed areas in the introduction with the following words. *'However, in established and built up areas where land is scarce, expensive, and where the opportunity to build in environmental improvements is limited, a different range of solutions will need to be considered'* - different being different from the range of solutions for greenfields areas.

With an increasing trend towards inner city living, it will be increasingly the developed areas that will be under pressure for the provision of adequate stormwater infrastructure and an appropriate form of stormwater management. However it is often those same areas that have yet to be provided with an adequate trunk drainage system, since the area was first developed 40 or 50 years ago.

## 7. 'MYTHS' AND REALITIES

Given the broad historical perspective outlined above, listed below are what I regard as the current 'myths' surrounding stormwater in Adelaide together with a more realistic assessment of the situation.

**Adelaide doesn't have a flooding problem**

How times change. Nearly twenty years ago, after the flooding of June / July 1981 followed by the flooding of March 1983, Adelaide was being touted as the most floodprone capital city in Australia. The establishment of a Flood Management Unit in the then E&WS Department had already been recommended (Joint State and Local Government Committee on Urban Flood Management, 1982). Now, nearly twenty years later, albeit after the implementation of some (but not an overwhelming amount of work), there appears to be little recognition of the problem.

In reality Adelaide continues to have a flooding problem. It is not as severe or as frequent as some other parts of the country but nevertheless it is still there. The minor flooding that regularly occurs in parts of Adelaide, together with the occasional larger events such as occurred in the early 1980s and more recently on Glen Osmond Creek at Wayville, are evidence of it. It is largely caused by the lack of adequate trunk and subsidiary drainage to drain water through and from the current development. I would suggest it is gradually getting worst, as redevelopment of the inner suburbs continues.

**On-site detention or retention can substitute for the provision of an adequate drainage network in developed areas.**

Unfortunately there seems to be a growing perception that the adoption of on-site detention or retention can solve existing drainage and flooding problems in developed areas.

A good example of this appeared in issue 81 of the Stormwater Industry Association Bulletin (SIA 2000). In this issue a small article appeared that advocated the mass installation of 'Rainsaver' gutters as a means of solving Melbourne's flooding problems. Not withstanding the practicalities of what was proposed, the article took no account of the variability of rainfall and the quantity of rainfall that can fall in a storm event.

Similarly, in areas faced with inadequate drainage infrastructure and on-going redevelopment pressures, there appears to be an impression that requiring the construction of on-site detention or retention storage will not only control the increased runoff caused by the new development but also alleviate the existing problems. (The seemingly ad-hoc requirement for such controls was one of the reasons for the preparation of the 'Guidelines for Urban Stormwater Management' referred to earlier.)

Unfortunately this is not normally the case. Unless a large redevelopment is proposed and sufficient land can be freed up for storage purposes or very large storage systems (well in excess of normal domestic tank sizes) are used for individual allotment redevelopment, the volume of water involved in even a moderately sized storm (>5year ARI) will render such devices ineffective.

In reality there is no substitute for proper planning, as advocated in the Urban Stormwater Management Guidelines. The two principal councils covered by the South-Western Suburbs Scheme have already undertaken some planning. With the advantage of an adequate trunk drainage network already in place, planning has proceeded to identify appropriate runoff controls (at various ARIs) to place on further development and redevelopment. This, combined with planned extensions to the drainage network, allows further development to take place without compromising the standard of the current system.

Conversely where the existing drainage system is already inadequate, placing limits on additional runoff normally only helps prevent the problem from getting worse – and normally only for the smaller rainfall events.

**Stormwater can make a major contribution to Adelaide's water supply needs**

The Urban Stormwater – A resource for Adelaide report estimated that there was 150 000 ML of runoff from all of Adelaide's urban areas. While some of this runoff from the Stirling / Bridgewater area, currently flows direct to a reservoir, the majority is generated on the Adelaide Plains. 150 000 ML was an initial estimate only but I am not aware of any published work that has updated this figure.

More importantly due to the variability of rainfall and the amounts that can fall during storm events, only a proportion of this runoff can be captured. For a larger wetland / ASR type capture scheme this proportion is dependent on the amount of land available to construct the required wetland prior to discharge to the bore etc. For two projects that are about to be constructed (Parafield and Morphettville Racecourse) the proportion is about 70%. This would be about the upper limit, as both projects are being constructed in relatively ideal conditions. As the availability of land drops so does the proportion.

The problem is that we are rapidly running out of suitable sites in the older part of Adelaide on which to construct such schemes. The best sites are already taken. Other seemingly attractive sites are required for other purposes (eg Adelaide Airport / Parklands) or have other expensive constraints (eg Port Road median which is riddled with underground services).

So far none of these projects have proved economically viable in their own right. All have been constructed using a pre-existing source of stormwater or have required government grants to fund construction. The lack of economic viability is related to the relatively low price of water. This will not be easy to change, as similar to petrol, there is a political imperative to keep the price as low as reasonably possible.

The low cost of water also hinders the adoption of on-site stormwater use systems. Unless there are incentives, similar to the solar hot water or photovoltaic rebate programs, or some new form of water pricing it is likely that the uptake or retrofitting of on-site systems will remain low.
There are also other more reliable sources of water (sewers, brackish groundwater, the sea) that through technological change could prove to a more viable alternate source of water in the long term. Another longer term consideration is that all current 'greenhouse' climate models are starting to converge on a scenario of less total rainfall, but more intense storm rainfall for southern Australia in the future (Pearman 2001). This implies less yield but higher peak flows (more flooding) in stormwater systems in the future.

Stormwater appears unlikely to become a major source of water. More likely it will remain on the margins, being used where conditions are favourable and funding is available (eg Parafield) or as part of WSUD in new developments (eg Mawson Lakes).

**Stormwater is a major contributor to the degradation of the marine environment**
I concede that the jury is still out on this one. While there is no doubt that stormwater has played a major part in the degradation of watercourses and estuarine waterways, where stormwater is the major flow component, its impact on the wider marine environment is less clear. Unfortunately the continuing discharges of treated sewage effluent and the previous discharge of sewage sludge have always masked the effect of stormwater on the marine environment.

Already only the south west suburbs and various smaller drainage systems strung along the coast, discharge stormwater directly to the sea via lined conduits. The rest eventually reaches the sea via unlined constructed channels, natural watercourses, large recreational waterbodies, detention basins, wetlands or rarely reaches the sea at all. Even simple unlined detention basins on the Southern Expressway have been found to be effective in reducing pollutant loadings (Johnston et al, 2000). Similarly the unlined Hindmarsh, Enfield, Prospect outfall drain showed substantial reduction in pollutant loadings compared with the adjacent lined drains (Daniell 2001).

That stormwater is more likely to be only a 'bit player' in this problem already appears to have been implicitly recognised, with most Catchment Water Management Board water quality improvement effort being directed more towards watercourses and estuarine waterways.
Very large sums have and will be spent by the State Government in diverting sewage sludge to land based disposal and upgrading effluent to a more acceptable standard for discharge to the sea.
Meanwhile the Adelaide Coastal Waters Study, which is just getting underway, should hopefully provide a definitive answer to this question. It may also provide a stronger basis on which to justify expenditure in this area.

## 8. CONCLUSIONS
From the single objective management of earlier times, stormwater management has rapidly evolved over the last decade or so to embrace a multi-objective approach. With it have come new catchcries and new ideas, along with the expectation that the new can sweep out the old.

This is not necessarily the case, as the options for local stormwater management are heavily constrained by the current development and established infrastructure. If Adelaide now wants to redirect its development in new directions and further encourage inner city redevelopment, its now time to accept the reality of the constraints that exist, develop appropriate policies, then plan and provide funding accordingly.

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# Historical aspects of the water supply to railway towns

Supplying the water needs of steam trains in South Australia during the 100 years, 1856 - 1956

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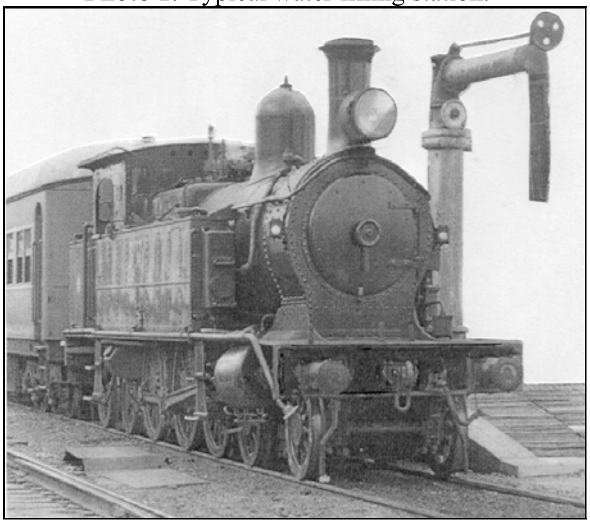
**Summary**
The enormous contribution of the steam train to the early development of South Australia was made possible in large measure by the ingenuity and resourcefulness of the early railway engineers. In many areas, water for the steam locomotives was a scarce commodity and making the best use of local sources was the challenge. Schemes devised included the pumping of groundwater, diversion of stream flows and harvesting of local catchment runoff. In the examples presented, it is clear that rainfall and streamflow variability, evaporation loss, and siltation, all variously had a major impact upon system reliability, particularly during extended periods of below average rainfall.

**Photo 1**: Typical water filling station.



## 1. BACKGROUND

Steam locomotives first entered service in Australia connecting Flinders Street station to Port Melbourne (Victoria) in 1854, closely followed by Sydney to Parramatta (New South Wales) in 1855, and Adelaide to Port Adelaide (South Australia) in 1856.

The beginning of a trunk rail network to the remainder of South Australia was commenced in 1857 linking Adelaide to Gawler. This network expanded greatly over the next 100 years until by the time most steam locomotives were phased out of operation in the late 1950s the network was over 5 500 kilometres in length.

There are a number of distinct periods of regional growth during this 100 years. The first occurred during the wheat boom of the 1870s (Central and Northern regions) and a second between 1895 and 1930 (Murray Mallee and Eyre Peninsula). Provision of steam train networks and adequate water supplies were both essential contributors to this growth.

Distance was a major constraint in developing and maintaining the expanding rail network. There were few daunting physical features to be overcome apart from the Mount Lofty Ranges and River Murray.

However, like the construction of extensive metal and wooden pipeline networks to service the water needs of country towns and likewise water tanks, rain sheds and bores for rural areas, the steam train networks also required access to secure water supplies. Water was needed to feed the steam boilers (locomotives) and for associated communities (railway towns).

## 2. WATER SUPPLIES

A plan of the rail network in South Australia dated 1951, Figure 1, locates in excess of 400 stations and sidings. Many of these were watering points and required a local water supply scheme.

Some were fortunate to be in close proximity to water reticulation networks servicing the larger urban centres and could tap into these supplies. Some were fortunate to be located in areas with assured groundwater supplies such as the South East or in areas with comparatively high surface water yields such as the Mount Lofty Ranges.

However, many were located in areas where the water cultivation potential is limited by comparatively low and variable rainfall and high rates of evaporation.

For instance, average annual rainfalls (Figure 2) in most northern areas of the State are less than 300 mm/y and evaporation rates exceed 2 000 mm/y.

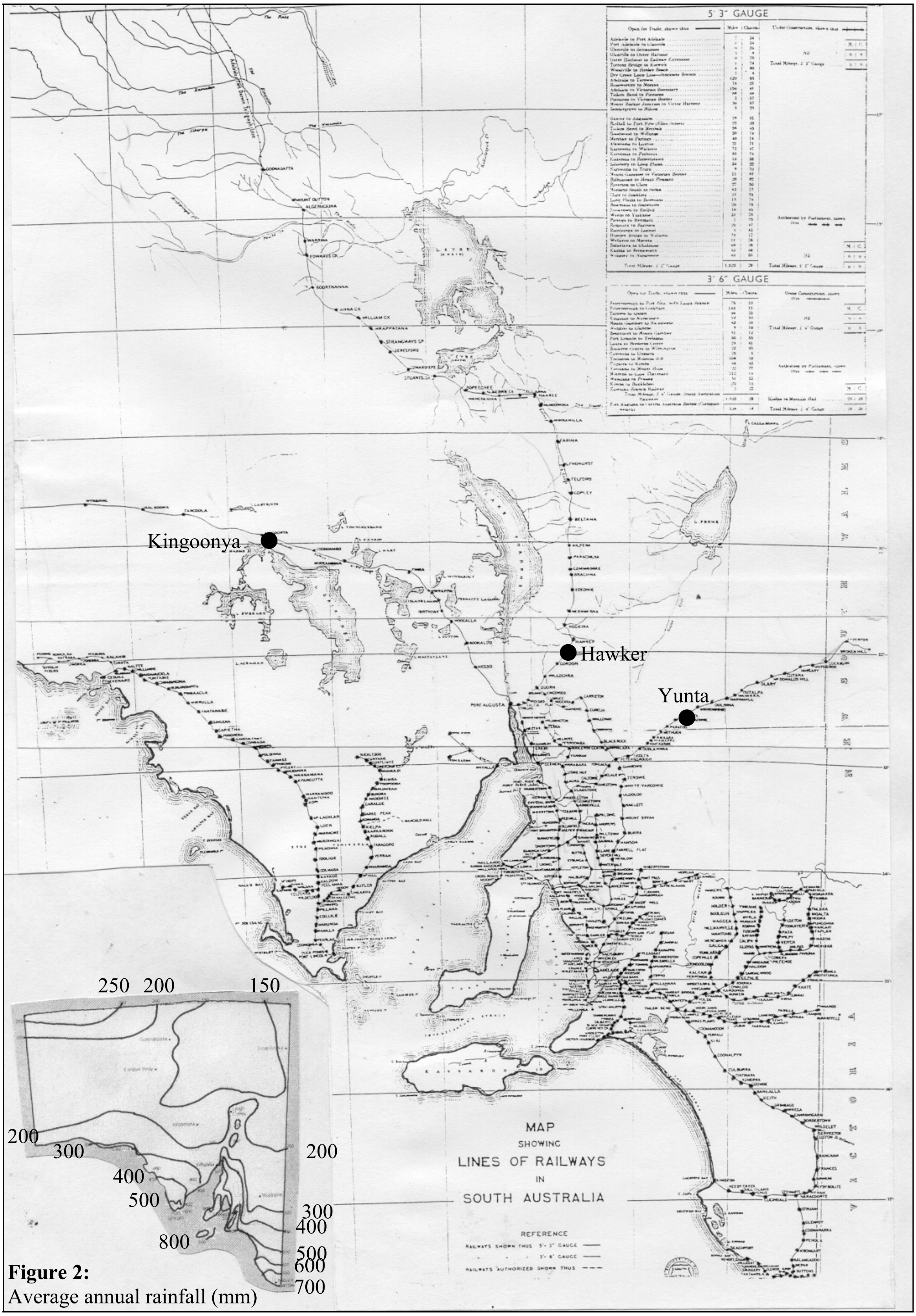



**Figure 2:**
Average annual rainfall (mm)

**Figure 1:** Railway networks, South Australia - 1951

A review of three railway town water supply schemes follows, which conveys the diversity of approaches utilised throughout the lower rainfall regions of the rail network in South Australia. These include:

(1) Pumping groundwater (Kingoonya)
(2) Diverting stream flows (Yunta).
(3) Harvesting local catchment runoff (Hawker).

### 2.1 Pumping groundwater

There are areas within the railway network where streamflow is irregular but where sufficient reserves of groundwater are available. Instances of this situation occur along sections of the railway between Port Augusta and the WA border.

For example, acceptable quality water is available from shallow locally recharged groundwater basins in the Glendambo area (example, Kingoonya).

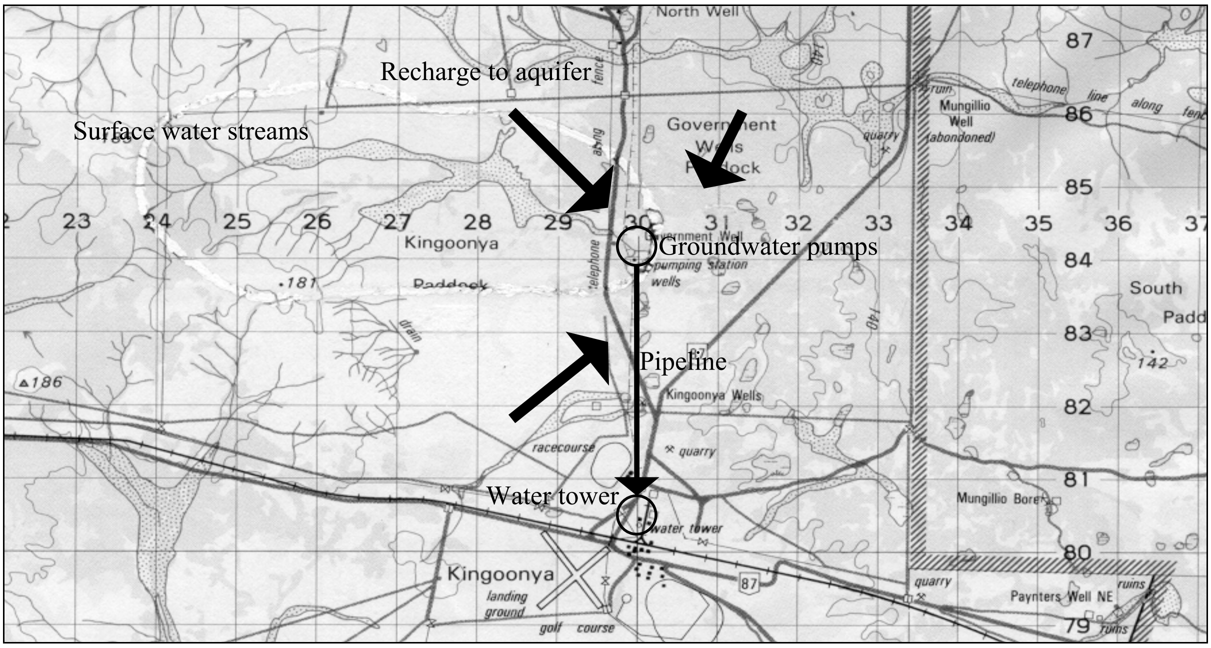



**Figure 3:** Water supply scheme layout - Kingoonya

**Water environment**

Kingoonya is now a largely abandoned town on the Trans-Australia Railway line, 43 km west of Glendambo.

Local topography is essentially flat with some low hills and poorly defined watercourses.

Annual rainfall and evaporation average 166 mm and 2 800 mm respectively. A review of historical rainfall records indicates that periods of 2 to 4 years of little or no surface water flow can be expected to re-occur relatively frequently.

Fortunately, when flows do occur, they are subject to natural recharge to an underlying groundwater aquifer. This aquifer comprises a thin layer of sandy clay underlain by various stratum of fine to course sandstone down to a level of 18 m.

Salinity ranges from 500 mg/L to 5 000 mg/L with samples taken in near proximity to the wells being generally less than 1 000 mg/L.

**Water supply scheme**

Water is pumped from the well field located 3 to 4 km north of the township to an elevated tank adjacent to the railway station.

The area in which the wells and pumping station are located (Photo 1) is subject to irregular, but on occasions, extensive inundation.

Evidence of previous flood heights enabled a rough check to be made on recharge estimates.

**Photo 2:** Recharge area- Kingoonya

**Effectiveness**

Estimates of recharge volumes supported by anecdotal evidence indicate that the groundwater resource had sufficient storage to maintain an adequate supply of water to the township, railway and local station properties, even during periods of drought.

However, careful management was required to minimise water quality degradation and reduced yields. This was particularly necessary during periods of concentrated withdrawal of water for road making purposes.

## 2.2 Diversion of stream flows.

There are many railway towns which are in close proximity to the wide flat-bedded streams typical of the Northern Flinders, Gawler and Olary Ranges.

Stream flows are generally irregular and subject to extremes of flood, drought and siltation. Evaporation rates vary between 2 000 to 4 000 mm per year.

A technique commonly used was to construct a low weir across the streambed and divert flows to off-stream storages. The water supply scheme for Yunta (population 85) provides a good example.

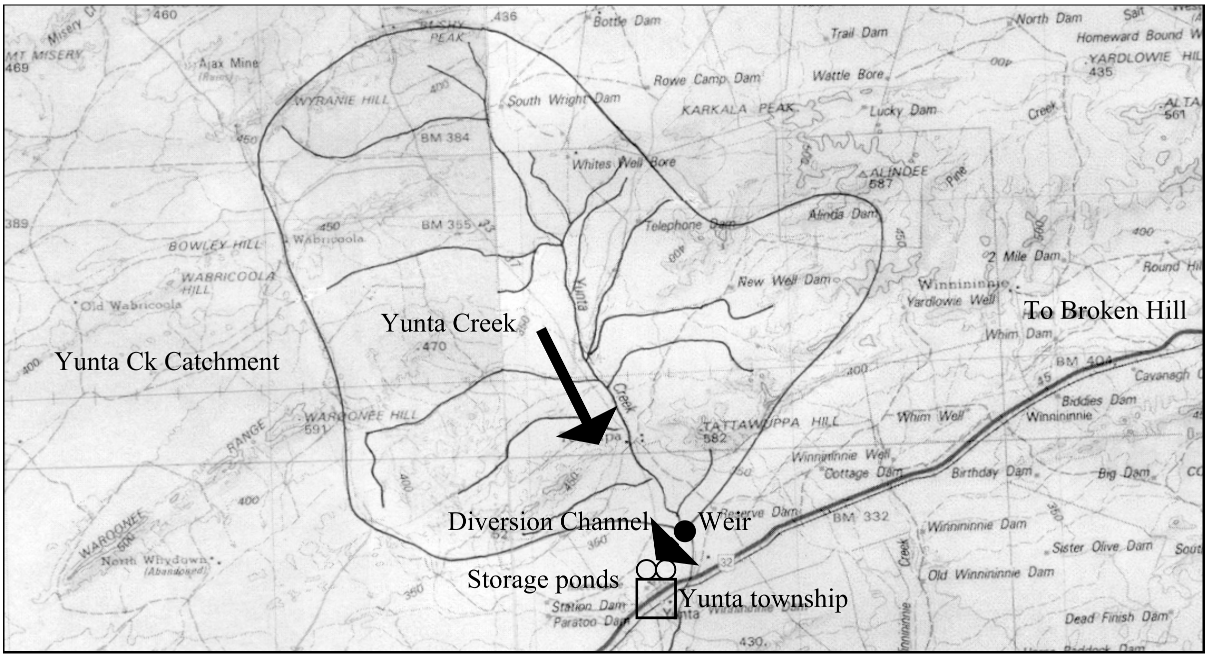



**Figure 4:** Water supply scheme layout - Yunta

### Water environment

The 680 square kilometre Yunta Creek catchment is located within the Olary Ranges.

Topography is typically flat to undulating with some hills up to 260 m higher than the invert of the weir.

Annual rainfall and evaporation average 254 mm and 2 500 mm respectively. Flows in the creek are irregular due to high rainfall variability and transmission losses.

The underlying geology is primarily fractured rock and groundwater resources are limited.

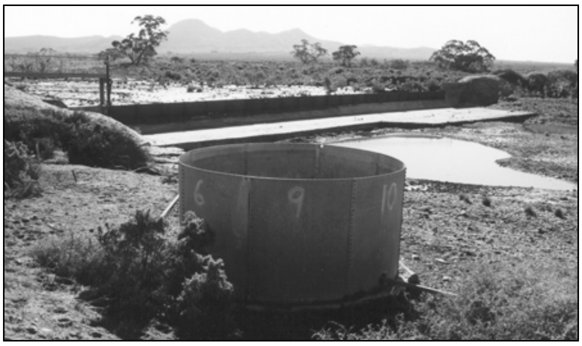
### Water supply scheme

A low weir supporting 22 adjustable steel gates (Photo 2) has been constructed across Yunta Creek some 3 km upstream of the town. Each gate is 1.0 m high and 1.5 m wide.

Water retained behind the weir is diverted under gravity along a 3.5 km long excavated channel to a large stilling basin and 2 storage ponds immediately north of the township. The ponds have a combined storage capacity of about 48 ML.

Salinity is acceptable provided that the gates are operated to preclude the higher salinity flows.
The SA Water Corporation now operates the scheme to provide Yunta's water supply.

**Photo 3:** Diversion weir - Yunta



### Effectiveness

Placing any form of structure in the streambed of Yunta Creek (or similar watercourse) inevitably results in the deposition of silt. This requires regular excavation and removal to keep the system functioning efficiently

Similarly, the gates are susceptible to clogging with tree trunks and other floating debris.

On occasions, irregular streamflows and the high rates of evaporation experienced result in the ponds drying up thus necessitating the costly carting of alternative water supplies from Peterborough.

### 2.3 Harvesting storm runoff

There are a number of railway towns where local streams are too small, too large, too salty or too far away for them to be developed in a cost-effective manner. One alternative variously adopted by some town was to harvest the rainfall runoff from local roads, roofs, hillsides and/or naturally occurring impervious surfaces such as rocky outcrops. The ex railway town of Hawker incorporated an example of this technique.

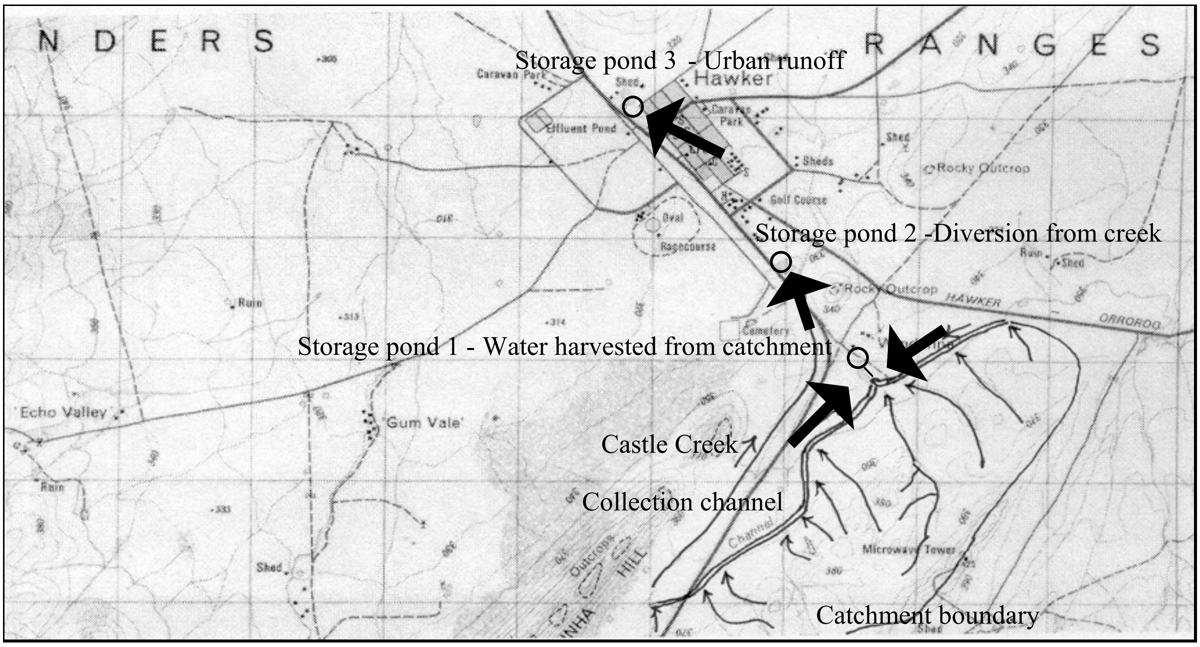



**Figure 5:** Water supply scheme layout - Hawker

**Water environment**

Hawker is located north of Goyder's Line in undulating country within the eastern foothills of the Flinders Ranges.

Annual rainfall and evaporation average 310 mm and 2 715 mm respectively. Rainfall runoff and stream flows are irregular.

**Water supply scheme**

Water supplies were originally provided from 3 storage ponds each tapping into different local water sources. Construction commenced in the 1880s.

Pond 1 stores water harvested from the low sparsely vegetated hills immediately south of the town. Runoff from this 9.2 $km^2$ catchment is intercepted by a network of concrete and earthen channels (photo 3) and directed via a gated spillway into a stilling basin and thence to the storage pond.

Pond 2 stores water diverted from Castle Creek via an earthen channel from the storage behind a 10 m high concrete dam with stepped spillway. This spillway is a rare example of early water engineering design. The storage is now largely filled with silt.

Pond 3 receives non-potable low salinity runoff from the streets of Hawker which are wide and have been sealed kerb to kerb.

Collectively, these components of the old Hawker water supply scheme are representative of the diversity of water management options available.

The current water supply to Hawker (population 345) is provided by the S A Water Corporation and sourced from groundwater bores, 4 km east of the town.

**Photo 4**: Cut off drain - Hawker

**Effectiveness**

Flood damage to the collection and storage system, irregular inflows, evaporation losses, reduced storage capacity due to siltation and variable water quality all contributed to a marginally reliable water supply system.

Water carting of potable water was required on occasions when ponds 1 & 2 ran dry.

## 3. IN RETROSPECT

The task confronting the early railway engineers in attempting to devise and construct durable and reliable water supply schemes under adverse hydro meteorological conditions was daunting.

The fact that the rail networks were constructed and steam train services maintained during the 100 years, 1856 to 1956, is testament to determination and initiative.

As with the settlers who pushed north of Goyder's Line based on the experience of a few good rainfall years only to be confronted by the reality of crippling drought, the early railway engineers had limited access to records of climatic variability.

As a result, there are a number of instances where the quantity and quality yields of railway town water supply schemes, though generally adequate during average and better years, became unreliable during extended periods of below-average rainfall.

Of the many contributory causes, perhaps the most frustrating must have been to watch the water stored during good rainfall years inexorably disappear due to evaporation.

Increasing the physical size of the storage pond, was no guarantee of increased reliability. For instance, in areas where the average annual evaporation rate is 2 500 mm/y, a depth of 5 m would only sustain a supply for approximately 2 years, irrespective of the surface water area.

Sequences of 2 consecutive years of below average rainfall are common with 5 sequences of 5 consecutive years being recorded during the 100 year period, 1896 to 1996, near Kingoonya (Example 1).

Responses to this operational hazard ranged from excavating deeper ponds with smaller surface areas to isolating the water surface from the sun by the erection of a roof over the water surface. Roofed storages were generally more inclined to be in the form of a wide trench in order to facilitate design and installation. A more recent innovation is the use of floating polypropylene covers, which incorporate an anchoring system around the edge of the pond.

Another problem encountered was a reduction in water quality due to the occurrence of higher salinities, particularly during low flow periods. This became apparent in circumstances where there was little control over the inflow to storage ponds.

Fortunately, many railway town water supply schemes, such as Yunta (Example 2), were constructed with an ability to control inflows.

Whilst maintenance was a continuing issue with on-stream diversion weirs, they were largely effective in ensuring that higher flow, lower salinity waters were diverted to storage, and lower flow, higher salinity waters were allowed to continue flowing down the stream.

Evidence of silt build-up behind in-stream weirs and dams is widespread in watercourses throughout the more arid areas of the railway network.

The impact of rainfall variability was not just confined to droughts and floods. Rainfall intensity also effected the efficiency of many water supply schemes. A year in which the rainfall was average but fell often, but lightly, would not result in as much runoff and streamflow as a year in which the same annual rainfall was more intense and fell over a shorter period.

Railway towns such as Hawker (Example 3) were vulnerable to this circumstance, particularly the runoff harvesting component. The gentle slopes and ill defined runoff pathways require relatively intense rainfall to satisfy losses and create runoff into the cut-off drains. Consequently, inflows to the storages are infrequent and evaporation losses became critical to the reliability of such water supply schemes.

One recent development in water management entails recharging surface runoff to suitable groundwater aquifers and away from evaporation.

## 4. CONCLUSION

Had the early railway engineers had access to longer periods of climatic data and more recently developed water management techniques, the excellent job achieved could have been further enhanced by an increased reliability of supply.

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# The modern Australian history of corporatisation and privatisation of water supplies and irrigation- lessons for the regulators

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*Countless millions of people have lived without love, but none without water,* Nachmani 1994

**Summary**
This paper looks at international and Australian history of regulatory theory with respect to privatisation and corporatisation of urban and irrigation water suppliers. There are many lessons from overseas that are relevant. The paper presents the components and elements of the Australian best practice model in sectors. The components of the model will be illustrated by a series of short, and two long, case studies to illustrate the problems experienced in Australia to date.

## 1. INTRODUCTION

There are three aspects to all models of private water supply utilities:

- Regulation & information (modes of regulation, the problem of asymmetric information, information discovery mechanisms, including public participation in setting standards[1]);
- Conduct regulation (regulation of prices, service quality, and investment, diversification, multiple regulators);
- Structure regulation (horizontal restructuring, vertical restructuring).[2]

Water policy development, like all complex policy processes, is a complex interaction of social and natural systems. The natural systems are only recently understood and issues such a global warming need now to be brought into the equation. The systems that existed prior to corporatisation were muddled [3] and complex and based on ideas of water supply and rainfall which were fallacious. These systems created a legacy of environmental problems (salinity) and economic problems (expectations of low prices for water) and legal problems (overallocation of water) which now need to be solved. The present model to solve these problems in Australia is corporatisation.

Policy initiatives are best seen as experiments in management rather than confident predictions (Dovers and Mobbs, 1997). Any modern day effective process requires an adaptive framework iterations from learning. As Gell-Mann (1994) states:

> *The common feature of all these processes is that in each one a complex adaptive acquires information about its environment and its own interaction with that environment, identifies regularities in that information, condensing those regularities into a kind of scheme or model, and acting on the real world on the basis of that schemata. In each case, there are various competing schemata, and the results of the action in the real world feedback to influence the competition between those schemata.*

The conventional economic liberalism theory and public choice theory suggests that privatisation is better, as a smaller state can allow private utilities to dispense better services to consumers (Buchanan and Tulloch, 1962). This assumes a number of factors such as a perfect market and well-funded regulators (Lyster, 2000). Other critics point out that this process can abuse human rights as systems of economic management can fail to consider disadvantaged groups. (McKay and Bjornlund, in press). The transfer of state monopolies to private monopolies does not always establish a robust market (Lyster, 4 April 1999)[4].

The history of past policy making endeavours in the place in question and the relevant culture are important advisers to the any water policy process. The perceptive history of past managerial situations is one of the inputs to a better understanding of system dynamics (Forrester, 1961; and Newell and Wasson, 2001). This paper will outline some issues with the early attempts at addressing the environmental, economic and legal issues in the context of the economic liberalism models selected by Australia.

[1] Public participation is integral to a pluralist theory of democracy, which can check excessive central power. Society is improved or at least kept more stable through participation in public life and faith in administration (Stein, 2000).
[2] Amended from Jourvavlev, 2000.
[3] Lindblom, 1959, in *The science of muddling through,* pointed out that the ideal way to make a policy decision can never be achieved because of the lack of time, historical information, intellectual capacity and sources.

[4] note 6 cites the example of Telstra, a monopolist determined not to lose market share, which allegedly engaged in restrictive trade practices by taking weeks to process forms for transfers to rival companies, and requiring its rival to act as debt collector for outstanding amounts. Telstra faces potential fines of $40 million if found guilty of breaching competition laws.

Corporatisation is the main model employed in Australia in the urban water sector with some full privatisation in the rural sector. The range of activities are outsourcing, corporatisation, partial and full privatisation. Outsourcing is used to conduct minor aspects of the business such as cleaning; corporatisation involves private sector management techniques being imported into a Government Business Enterprise; partial privatisation involves the State retaining shares in the organisation and the balance being transferred to the private sector; full privatisation is where the private market has full ownership and control and is achieved by sale to the highest bidder.

## 2. HISTORY OF REGULATORY THEORY WITH RESPECT TO PRIVATISATION OF WATER SUPPLIES AND IRRIGATION

Private water utilities were common in 19th century England, for example Bristol Water, but fell out of favour and most counties replaced the private sector by public authorities (McKay, 1994), or set up their water supply bodies as public institutions. The present move toward the privatisation of water authorities has about a 15 year history, with England taking the early initiative and Australia following in 1994 (McKay, 2001). The privatisation push has been executed in many third world countries, see Table 1. Notably the purchasers have been English and French companies.

**Table 1:** Selected world cities water supply management regulatory structure.

| | |
|---|---|
| Auckland | Service contract |
| Bangkok | Service contract |
| Buenos Aires | Concession |
| Chengu | BOT |
| Colombo | Regulatory |
| Ho Chi Minh city | BOT |
| Hong Kong | Government owned |
| Jakarta | Concession |
| Karachi | Concession |
| Kathmandu | Lease |
| Kuala Lumpur | Lease |
| Macau | Concession |
| Manila | Concession |
| Oslo | Corporatised |
| Santiago | Concession |
| Stockholm | corporatised |

Sources: various World Bank publications (Dumoi, 2000 and Guislain 1997). Concession means fully private.

> *Water supply is a classic case of a local natural monopoly…. Private ownership does not make the natural monopoly go away. Simply converting a public monopoly into a privately owned monopoly one provides few if any incentives to reduce costs, innovate, invest to the efficient level and respond to consumer demands…(*Jouravlev, 2000).

In England, the most recent trend is to move from full privatisation to mutual companies with much broader shareholder base ie all customers. Privatisation is seen as a transition step in turning around inefficient utilities, not a final destination. Mutualisation means selling the water assets to a company entirely owned by its customers.

Competition law has been used in Australia to regulate private utility behaviour and our competition laws are some of the most comprehensive in the world. In jurisdictions where such laws do not exist, one wonders at the remedies for consumers.

## 3. THE REASONS FOR PRIVATISATION ON THE GLOBAL SCALE

Water is scarce and demand is doubling every 21 years. (Legge, 2000). Multinational corporations recognise these trends and some argue that they are trying to monopolise water supplies around the world. Monsanto, Bechtel, and other global multinationals are seeking control of world water systems and supplies (Barlow 2001, Maude Barlow, chair of the Council of Canadians). The World Bank recently adopted a policy of water privatisation and full-cost water pricing. This policy is causing great distress in many Third World countries, which fear that their citizens will not be able to afford for-profit water. Grassroots resistance to the privatisation of water has emerged as companies expand profit taking. San Francisco's Bechtel Enterprises was contracted to manage the water system in Cochabamba, Bolivia, after the World Bank required Bolivia to privatise. When Bechtel pushed up the price of water, the entire city went on a general strike. The military killed a seventeen-year-old boy and arrested the water rights leaders. But after four months of unrest, the Bolivian government forced Bechtel out of Cochambamba (Barlow 2001). Such stories often lead for calls that governments must declare water a fundamental human right. (Gliek P, 1998).

As Barlow states very forcefully:

> *Governments around the world must act now to declare water a fundamental human right and prevent efforts to privatise, export, and sell for profit a substance essential to all life.*

Research has shown that selling water on the open market only delivers it to wealthy cities and individuals. Governments are signing away their control over domestic water supplies by participating in trade treaties such as the North American Free Trade Agreement (NAFTA) and in institutions such as the World Trade Organisation (WTO). These agreements give transnational corporations the unprecedented right to the water of signatory countries. Water-related conflicts are springing up around the globe. Malaysia, for example, owns half of Singapore's water and, in 1997, threatened to cut off its water supply after Singapore criticised the Malaysian government's policies. Monsanto plans to earn revenues of $420 million and a net income of $63 million by 2008 from its water business in India and Mexico. Monsanto estimates that water will become a multibillion dollar market in the coming decades.

The lessons from privatisation in the above countries are hard to distil and there are differences between them. From England, it has been observed that privatisation may weaken or even disrupt the promoted idea of integrated catchment management, in favour of single purpose water management, and this happened with the dismantling of the regional Water Authorities in England and Wales (Kubo, 1994). Thus, the benefits of multipurpose management, like the possibility of cross subsidies across services, within a unified management organisation will be lost (Cesano and Gustafsson, 2000).

From Asia, it has been observed that customers have few rights because they do not have adequate consumer protection laws and price rises have created water-rich and water-poor groups.

In Australia, we have seven different models proposed in the new Water Acts. There are five main issues (Jones et al, 2001). The primary issue concerns the recent Water Acts and the inherently difficult problems of making decisions to satisfy multiple conflicting aims. Clearly, trade offs will exist, but in view of the vexing nature of the issues, ie reducing water allocations and rising prices, there is likely to be community angst and litigation. The objects section of each Act is crucial, as the words there will be used to interpret the Act in the event of a dispute.

The new Water Acts are designed to promote a public benefit of creating sustainable resource use. Hence, any ambiguity would, I feel, be construed in favour of protecting the resource. Indeed, generally speaking, all these Acts have reversed the ordinary presumption that Acts should be construed in favour of the person losing a right. These Acts all aim to make protection of the water resource the first goal[5]. However, each Act includes five goals in its objects, and one of these is fairness or equity.

Each Act in its objects sets out a number of contradictory goals. In short the five major themes are:

- to apply ecologically sustainable development;
- to protect and restore water courses;
- to enhance the social and economic benefits to the State;
- involve the community; and
- provide for orderly and equitable[6] sharing of water.

Such themes are in themselves contradictory and so the community needs to look to the regulatory approach and institutional frameworks set up in order to be able to make choices when conflicts arise. Merely making it compulsory to consider them all cannot satisfy these aims. Judges will incline toward fairness in interpreting these Acts despite the preponderance in some of them toward the environment. So the fairness criteria may tend to undermine some of the ecological objectives unless it is removed, as in South Australia.

[5] some more explicitly than others.
[6] SA does not require equitable.

There are four related issues. The first issue is that these Acts do not cover the entire area of water management in any State of Australia. Many other Acts are relevant, notably the Environmental Protection Acts and the Acts allowing for development of land in each State. Until each jurisdiction enacts a single Act, then all relevant legislation needs to be included. Indeed, until roads, land-use and the many other decisions are made on a watershed basis, then the water concerns and management of water to achieve the criteria will be difficult.

The next issue is of unclear meanings in the Water Acts. Most of these laws are very recent, and so no cases exist on them. However, cases would exist on the preceding statutes, and such cases may transform the legal meaning given to the words in that jurisdiction. In addition, there exists the likelihood of High Court Cases such as *Gartner v Kidman* ((1962) 108 CLR 12), which would influence the direction of a decision in the future on the meaning of the words in the statutes such as “watercourse”. In addition to High Court decisions, there will also be pre-existing Acts within the same jurisdiction which would influence decisions, such as Native Title legislation, Environmental Protection Laws, Mining Laws, Acts Interpretations Acts and the Laws of Evidence, to name a few. In addition, later Acts in the same jurisdiction will influence the subsequent interpretation of these Acts. In Victoria and South Australia, pre-existing groundwater-sharing Acts still prevail over the new Acts[7]. Finally, Australia has entered into many treaties and these may also influence decisions on the meaning of the concepts used in the various statutes.

Another issue concerns the duties of the directors of the Boards (see case study below on Goulburn Murray Water) and if they have training. Also, obligations exist on the Board to consult the community but the methods to do this are not specified.

There are also issues concerning the type of obligation imposed on the relevant body, ie if they **must** do or **may** do something.

## 4. THE HISTORICAL LEGAL ISSUES IN AUSTRALIAN WATER MANAGEMENT

The federation of Australia in 1901 was a contested issue and the eventual political compromises resulted in water remaining with the underlying States.

The Commonwealth did have direct power over water in the Territories but the list of enumerated powers in section 51 did not mention the environment or water at all. The powers in section 51 are broad and include power over trade and commerce. It was because of this power that Section 100 was inserted to protect the rights of the residents of the States to the reasonable use of rivers for conservation or irrigation. Section 100 was inserted because New South Wales, Victoria and South

[7] section 6 of the *Water Act Victoria 1989* as amended.

Australia feared the Commonwealth trade or commerce laws might affect their common interest in River Murray Waters (Lane, 1986). Section 100 states that:

> *The Commonwealth shall not by any law or regulation of trade or commerce, abridge the right of the State or of the residents therein to the reasonable use of the waters of the State for conservation or irrigation.*

The States evolved from a set of colonies which had each spent near to 100 years developing its own way of operating. Water was no exception and the operating models will be described in the next section.

## 5. THE LEGAL AND REGULATORY MODEL IN EACH AUSTRALIAN STATE PRIOR TO CORPORATISATION REFORM IN 1995

Each State developed its own style of water resources management with unique acts and unique institutions that evolved from a complex history of partisan political negotiations. (McKay, 2001 and Hallows and Thompson, 1999). In the 1990s there were more than 800 State Authorities, metropolitan water Boards, local government Councils, irrigation bodies and some companies and individuals involved in water resources management (Boughton, 1999). Despite the large number of bodies, the era was characterised by cooperation between these bodies intra State and the bodies were persistent. However, the State bodies were extremely internally focussed (McKay, 1994) and heavily constructionalist. Between 1900 and 1909, 19 % of present dam capacity was built and in the 1970s to 1980s 44% of Australia's large dam capacity was built (Boughton, 1999, p ii). The dam capacity as at 1990 is 78.92 $km^2$ of which one third is in New South Wales and one third in Tasmania and one sixth in Victoria. Despite this construction, it has been reported that an overall understanding of Australia's water resources was vague until 1962. Different States collected stream-flow data differently, therefore making data compilation difficult and even within one State, different agencies did not collect data in a way that made it able to be used with data collected from other agencies. This was true particularly for water quality data which has to date been very poorly reported (McKay and Moeller, 2000, pp 165-175). All the water allocation policies were introspective (Bjornlund and McKay, 1996, pp 315-332) as each State looked only at its own rivers and New South Wales considered the Murray to belong to it only (Boughton, 1999, p 205). It took until 1915 to draw up an Agreement over the River Murray between three States and until 1992 to add Queensland. In 1917, the River Murray Commission was set up but was limited to dealing with the main branch of the River. The powers and scope of the Commission have been steadily expanded since the 1970s and now the Commission embraces many powers with the objective of coordinating and promoting the effective planning and management for the equitable, efficient and sustainable use of the water, land and other environmental resources of the Murray-Darling Basin.

Up to the 1970s, the water resources laws of each State promoted irrigation developments in inland Australia to develop and populate the land. Water supply was heavily subsidised. The settlers were either soldiers from both world wars or immigrants from Britain. Hence, the State Governments had to provide water, which it did out of its own resources and in cooperation with the Commonwealth, for example through the Snowy Mountains Scheme in 1940s. Hence, State Governments were given funding in the early days to divert rivers and go far afield to ensure water supply. New South Wales was best at this, and today Sydney stores more water per capita than any other major city in the world: sufficient to continue supply through an eight year drought (Boughton. 1999, p 30)[8]. The impact of all these developments and especially the unfettered spread of irrigation, created large-scale salinity problems. These were noted in the national arena in the 1970s, by the Senate[9] and salinity on the Murray River was then reported as one *of our biggest water pollution problems* (Senate Select Committee on Water Pollution, 1970).

Hence, in the 1978 agreements for the Commonwealth to fund water resources developments under the *National Water Resources Financial Assistance Act*, funds were provided on broader heads than ever before. Funds were provided to conserve water, manage water quality, desalination and flood mitigation. The *National Resources Management( Financial Assistance) Act* 1992 widened the range of eligible activities to include an integrated approach to management of land, water, soil and vegetation. (Tan, Poh-lin, 2000, pp545-557)

This shows that the development of Australian water resources has never been a steady process, but one marked by failures and successes of a physical, environmental, technological, institutional or political kind (Johnson and Rix, 1993).

The water industry in the 1990s was one of Australia's largest with assets, valued at over \$90 billion in replacement costs, with about half of this in rural areas (Productivity Commission, 1999, p 131). However, the Productivity Commission went on to say that water has often been poorly managed and that environmental degradation and associated economic and social costs are particular problems in the water sector.

## 6. THE REASONS FOR THE CORPORATISATION WATER REFORM PROCESS IN AUSTRALIA

The reform process was driven by the appreciation that the subsidised water prices for households and irrigation had led to over-consumption of subsidised water, which has led to environmental problems. Furthermore, there were examples of water being used to win votes in 1989 in Queensland by major allocations of licences. In addition, the communities in the rural regions

[8] Sydney has a population of 4.5 million people.

[9] The upper house on the Federal system, which has equal numbers of Senators from each State.

recognised the problems and, with national funding, were able to be mobilised into Landcare groups. Up to 4200 groups exist today (AFFA, 1999) to do works such as fencing to protect natural resources from further degradation.

The National Competition Reform process was driven by the 1990 and 1992 inquiries by the Federal Government Industry Commission. The 1990 report found a low rate of return on capital invested, as low as 1.5% in 1987-88 (Industry Commission, 1990). In 1992, the Industry Commission called for major institutional change and pricing reform. In 1997, the Industry Commission also produced a report on Ecologically Sustainable Development and engaged the community through a series of hearings in each State (Industry Commission, 1997).

## 7. THE LEGAL INSTRUMENTS AND REGULATORY MODELS OF THE COAG WATER REFORM PROCESS

The reforms were set against this background of concern over water resources management, in particular environmental problems, and the need to reform water pricing and water rights, in order to encourage future economic development. At a meeting in June 1993, COAG concluded that there were still significant economic and environmental benefits to encourage future reform. An independent committee was set up, and the strategic framework generated provided the background to the three agreements set out below.

The National Competition reform process is set out in three inter-governmental agreements (States and Federal) signed in April 1995. These are the: -

1. *Competition Reform Act*;
2. Competition Principles Agreement; and
3. agreement to implement the National Competition Policy (NCP) and related reforms.

These are discussed below.

### 7.1 Legal instruments to adopt the water reform process- *Competition Policy Reform Act 1995*

The reforms of the former government-owned enterprises were enacted into law by each State. There was constitutional uncertainty as to whether the Federal *Trade Practices Act 1974* could be extended to cover State government businesses, as these generally operated in one state as seen above. Hence, the legal mechanism used to achieve the extension of the anti-competitive conduct regime of the *Trade Practices Act* was for each State to enact in its jurisdiction, in 1996, a modified version of Part IV called the "Competition Code" These were template laws, all copies of each, a legal mechanism used before to enact the Corporations Law. In that situation, that was done because the Commonwealth has no power to pass laws to form corporations (NSW v Commonwealth 1990 8 ACLC120). The Commonwealth also has no direct power over water, see above.

The new Part 1V of the Trade Practices Act prohibits a range of anti- competitive conduct including:

- anti-competitive agreements;
- misuse of market power;
- exclusive dealing;
- resale price maintenance; and
- mergers which have the effect, or likely effect, of substantially lessening competition.

### 7.2 Competition Principles Agreement

The National Competition Reforms seek to address economic viability and ecological sustainability of the nation' s water supply through the following measures:

- pricing reform based on the principles of consumption-based pricing, full cost recovery (urban by 1998 rural by 2001) and removal of cross subsidies, with remaining subsidies made transparent - encouraging people to use water more wisely by basing their consumption decisions on prices reflecting the actual value of the water they use;
- water allocations or entitlements, including allocations for the environment, coupled with trading in water entitlements - allowing water to flow to those activities bringing maximum benefit to the community[10];
- improved water quality monitoring and catchment management policies and a renewed focus on land care practices to protect rivers with high environmental value;
- future investment in dams and other water infrastructure being undertaken only after appraisal indicates that it is economically viable and ecologically sustainable - addressing the need for cost efficient investment with due regard to environmental concerns; and
- structural separation of the roles of service provision from water resources management, standard setting and regulatory enforcement.

### 7.3 Agreement to implement the National Competition Policy and related reforms

This incorporates COAG agendas for electricity, gas, water and road transport industries into the NCP framework. The agreement also sets out conditions for financial assistance (under section 96 of the Constitution) from the Commonwealth to those States that implement the NCP reforms in the timetable set for implementing reform. The total financial incentives between 2000 and 2006 amount to $16 billion. The timeframe for reform in the water sector was set at 5 to 7 years from 1994 because of the sheer size and complexity of the package (Bjornlund and McKay 2000).

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[10] Bjornlund and McKay (2000) found in various studies that water trading had moved water to higher value uses. This work is on rural water of the GMID, which is the subject of the case study later in this paper on all aspects of its operations, and the mechanisms adopted to conform with NCP.

### 7.4 Performance monitoring and benchmarking

This has evolved to the extent that at first eighteen [11] but now twenty one (WSAA Facts 2000, foreword) of the major urban providers in all jurisdictions actively participate in performance monitoring through reporting to their industry lobby group the Water Services Association of Australia (WSSA). WSSA was formed in 1995 to provide a forum for debate on issues of importance to the urban water industry and to be a focal point for communicating the industry's views (WSSA Annual Report, 1999, foreword). WSSA members are drawn from businesses that provide water to 50 000 people, either directly as retailers or indirectly as wholesalers. WSAA Facts has recently gained the endorsement of the National Competition Council as meeting the industry benchmarking requirements of the National Competition Policy (WSAA facts, 2000, foreword).[12]

In addition, 64 non-major urban water utilities are compared against 74 performance indicators on water and sewage services, and irrigation benchmarking reports are in progress. These are all voluntary, and it is stated that this competition by comparison approach will lead all water service providers progressively to adopt best practice (Report at p 23).

### 7.5 Regulatory framework

At 30 June 1999 the Second Tranche Assessment of Governments' National Competition Council (1999) progress revealed this picture of institutional reform:

The functions of regulation, standard setting and resource management have been removed from service providers. However, significant work remains to be done in this area at June 1999.
Sydney water is one model of the regulatory scheme, but NSW changed the model because of flaws detected in the Sydney water crisis (National Competition Council, 1999, at p 275). The elements of the regulatory framework are set out in the *Sydney Water Act*, to protect public health by supplying safe drinking water to the public. The elements of the system were an operating licence (McKay and Moeller, 2000) which sets the operating and customer standards to be met by the Corporation, a license regulator created by the Act to monitor the Operating Licence, and a Memorandum of Understanding required between Sydney Water and NSW Health. This last agreement has been subject to change after the Sydney water crisis. One result of the confusion over the issue (Hawkins, 2000) was the recommendation that an independent laboratory be set up, and that the monitoring program needs to have clear linkages between public health and operational decisions.

The Australian Consumer and Competition Council (ACCC) has found the ability of regulators to watch the activities of utilities closely to be 'patchy' (Asher, 1999, p24) and generally in Australia we have had a low key and underfunded approach to business regulation enforcement (Grabosky and Braithwaite, 1986). It is alleged that the 1998 Sydney Water Board "essentially wrote its own licence" and there was no legislative requirement for public consultation or accountability in licence drafting or amending (Sydney Water Inquiry, 1998, p6). The Sydney water inquiry suggested that the role of the regulator be strengthened and any new operating licence clearly outline the obligations of Sydney Water and the role of a water auditor (Sydney Water Inquiry, 1998, Ch 2, p10, and Ch 10, p6).

## 4. OUTLINE OF THE LEGAL INSTRUMENTS AND REGULATORY MODELS IN EACH STATE

It is apparent from above there will be many instruments used to achieve the multiple aims, and the instruments chosen will depend on the past history of the State. The scope and pace of reform has differed in each State but the key aspect has been seen to be institutional and legislative reform (Ministerial Council, 1999). NSW and Victoria advanced the most in the first four years. In this section, a selection of the key aims of the COAG reforms will be illustrated and the approach and instruments used by the particular state will be outlined.

### 4.1 Australian regulatory models and legal instruments for the rural sector

**1 Aim**: structural adjustment in rural communities of NSW. The NSW Government adopted a $33 million structural adjustment package to assist irrigation farmers to adjust to the new water management arrangements. The package targets farm businesses planning, irrigation skills training, financial assistance for water effective techniques and technologies and re- establishment assistance where required.

**2 Aim:** land and water management plans in NSW. A sum of $200 million has been committed to support land and water management plans to provide a sustainable future for key agricultural areas. The adjustment package will be refined in conjunction with socio-economic analysis to be conducted as part of the water reform implementation package.

**3 Aim**: full cost recovery pricing in South Australia. Implemented through a levy, but SA has decided against full cost recovery pricing and instead has deemed it a Community Service Obligation to provide water and so will cross subsidise. However, such subsidies will be transparent. Costs of natural resource use are being recovered through a levy on water allocations and /or

[11] In 1999 see Report at p 23

[12] The foreword goes on to say that Development of sound policy requires information on key industry issues such as water resources, public health, water services and the environment. The cost of providing the level of service demanded by customers, and the industry regulators, is a particularly important issue. An understanding of the trade-offs between service levels, risk and cost is vital to achieving outcome-focussed regulation of the industry.

use in certain water resources Prescribed under the *Water Resources Act 1997,* such as the River Murray.

**4 Aim:** privatisation of Irrigation Districts in South Australia. On 1 July 1987, the SA Government transferred all of the Government Highland Irrigation Districts to 8 self-managed irrigation trusts. These bodies created the Central Irrigation Trust to employ staff and provide day to day management and operational services for all of the trusts. The legislative base was the *Irrigation Act 1994*, which was substantially amended. The head-works of all irrigation districts have been rehabilitated involving complete replacement of the old open channels with fully piped, computerised water on order system. The rehabilitation process resulted in more than 43% of properties being retired from irrigation on a land suitability basis. The trading regime allowed water and land owners to realise the value of either or both. The water savings from these properties form efficiency gains, and the water delivery system has been used for high value development and maintenance of river health.

**5 Aim:** water allocation and entitlements including environmental allocations in Victoria. The *Water Act 1989* as amended provided a legislative basis for property rights in water. The process of conversion to bulk entitlements has reached a stage where 70% of the diversion sites across the State have been negotiated and agreed with stakeholders. The bulk entitlements program enables the provision of water for the environment and a range of negotiations has achieved improvements in environmental allocations. Victoria instigated a community consultation program under the banner *Sharing the Murray* in 1997. The committee of 35 members set out to clarify and define existing entitlements to water, and to show how the CAP on water use implemented by the Murray Darling Basin Committee would be implemented. The long consultation process with 8 water user members, 13 from irrigation authorities, 7 from environment and catchment groups and 7 from Government worked carefully to reconcile the interests of these competing groups.[13]

Key points in *Sharing the Murray* were:

- water rights, licences and urban entitlements to be kept very secure;
- if severe drought occurs, all basis entitlements to be cut back evenly;
- no cancellation of unused licences - some fall in the availability of lower security sales allocations but still some will be provided in line with past assurances; and
- improved environmental provisions to ensure adequate watering of important forests and wetlands.

[13] Progress Report says this did reconcile competing interests.

**6 Aim:** pricing reform Western Australia. Full cost recovery is being implemented through customers paying the full cost of water distribution and a transparent Community Service Obligation (CSO) being paid to the Water Corporation for costs not recovered from bulk water charges to irrigation service providers. In rural areas, transparent CSOs where the cost is higher than the cost to the major capital city Perth[14]. The uniform pricing policy reflects the State Government's strong commitment to regional development.

### 4.2 Case study Goulburn Murray Water rural and urban supplier Victoria

Goulburn Murray Water (GMW) is a statutory authority with powers defined and limited by the *Water Act 1989* (VIC) and empowered by Ministerial Order under the *Water Act* (Goulburn Murray Water Corporate Governance Manual, 2000, Sept, p1). The *Water Act* imposes a duty on all bodies in Victoria to perform functions in an environmentally sound way as it plans for State and local community use of water, for future water needs and to educate the public. GMW was one of the earliest bodies created under the COAG reforms in 1994 when it took over most of the irrigation, water, urban supply and flood protection districts formerly managed by the former Rural Water Corporation. The *Water Act* creates GMW as a body corporate. GMW is responsible to the Minister administering the *Water Act* and Parliament for the proper, efficient and effective performance of its statutory functions, and its objects are to deliver to its customers, in the most efficient and cost effective way, the services which the *Water Act* requires it to supply.

In doing the above GMW has, nevertheless, adopted commercial approaches to governance derived from the Australian Corporations Law as it *strives to manage its business in a way which is consistent with best practice in the private corporate sector* (Goulburn Murray Water Corporate Governance Manual, 2000, Sept, p1). The GMW has adopted 'directors' instead of the term 'members' as in the *Water Act* and uses 'Board' instead of 'Authority' in order to reinforce the above. This may be confusing to the customers, as the whole concept of corporate governance is hardly clear in Australia, as to whether it involves only shareholders and managers, or all stakeholders (Hill, 1999, p288-302). There is a fundamental confusion in Australia at the moment as to whether Corporate Governance should be concerned with managerial accountability or with enhancing corporate efficiency. The GMW manual seems to want both with a heavy lean toward the first because of the restrictions placed on this enterprise by Section 40. Most non-government businesses would focus on the second aspect and rely on *AWA v Daniel's* case (AWA v Daniels trading as Deloitte Haskins and Sells (1992) 7 ACSR 759)[15] to ensure that outside directors and

[14] has 80% of the population

[15] In that case, AWA sued its former auditors for a loss of $49 million in speculative hedging by a young and inexperienced foreign exchange manager in the firm.

executive directors were diligent because of the threat of liability.

GMW also has a significant set of delegations such as to 'construct works' and 'take and use water for waterways and bores'. In addition, the *Murray Darling Basin Act 1993* is the Victorian version of the *River Murray Agreement Act* [16]and this nominated the GMW as the constructing authority for the Agreement in Victoria. This is a significant delegation bringing with it a need to maintain capacity in construction and maintenance of major dams. In respect to these delegations, GMW is obliged to be in the first place answerable to, and must observe directions given by, the Murray Darling Basin Commission (Ibid note 30 at 3). To address the issue of conflict between requirements of the *Water Act* and this delegation, the Corporate Governance Manual is not very helpful. It says the Board needs to be *aware of the possibility of such conflict and to deal with such conflict with great care* (Ibid note 30 at 3).

Corporate planning is governed by the *Water Act* which requires a plan for the next year to be submitted by 30 April. This plan sets out charges and tariffs. The Board has established Committees and have power delegated to them by a series of administrative authorisations. This feature is very similar to the old structure prior to COAG except there is a Code of Conduct in place borrowed from the Corporate Sector (Corporate Governance Manual p8, see McKay, 1994). This imposes all the duties of due diligence good faith, improper use of information and conflicts of interest. It is questionable how meaningful this is in the corporate sector (McKay, 1992) with many codes not being looked at by directors and many directors being unsure of the limits in such general words. Section 90 does provide a civil immunity for acts done in good faith.

GMW ensures that its directors perform to best practice by:

- induction of directors;
- giving them a copy of all relevant documents;
- encouraging them to visit the web site;
- informing directors the obligation is placed on GMW to seek to provide directors with …*all information which is necessary or desirable for the director to perform the director's functions* (Corporate Governance Manual p11). This leaves many defences possible;
- training the director by paying for the Director to undergo training or attending conferences, allowing a limited facility for GMW to pay for the director to obtain independent advice; and
- requiring the director who receives representations from a customer to deal with those in a formal way.

GMW is audited under the *State Government Audit Act* (this also is identical to the old regime).

GMW has little autonomy, so it is strange the insistence on following rules for Corporate Directors which evolved in a very different circumstances. GMW must exercise its functions within the framework of government policy, as set out in section 40 of the *Water Act*. This means the conservation policy of the government, and the government policies concerning the preferred allocation or use of water. Government policy is ascertained through the use of the Corporate Plan, Policy Discussions and Ministerial Direction.

## 5. URBAN SECTOR

This section will provide a set of small case studies and one leger one illustrating the instruments used to achieve the reforms.

**1 Aim:** pricing reform with independent prices Authority NSW. NSW has set up Independent Pricing and Regulatory Tribunal (IPART) that releases a determination for bulk water charges. IPART made an attempt at estimating full, efficient cost-recovery levels by region, consistent with guidelines set by the Federal Government**[17]**. The Federal Government has set up a national project to help jurisdictions to develop a methodology that permits the identification of water related costs and guidelines for sharing the costs between government and private users to avoid environmental costs being borne by the community. Explicit guidelines have been recently sent out for public comment.

**2 Aim:** bring water pricing into closer alignment with consumption and cost of supply Queensland. The new 'pay for use' pricing and metering in the Brisbane area reduced overall consumption of water by 20% (National Competition Council, 1999). In rural areas, a three staged process has begun since 1999 with five year price paths.

**3 Aim:** review of water legislation for anti-competitive provisions. South Australia. The NCP process requires a regulatory review of each Act. In South Australia, the *Water Resources Act* was reviewed in relation to whether it was anti-competitive. It was found that whilst some aspects are anti-competitive, these same provisions generate net benefits by minimising the risk of environmental degradation and disputes over water usage. Therefore, they were retained.

**4 Aim:** to oversee performance of water and sewage companies. Victoria has set up the Office of the Regulator General, and each body must provide a performance report. For Melbourne, the major city with a population of 3.5 million, the Performance Report

Prior to the losses the exchange manager gave the impression of success and maintained the illusion. The company had no internal controls that the Auditors reported to management, who did not act on it and did not report it to the Board. The CEO of the auditors who was Chair of AWA Board, was found to be negligent in not passing on the Auditor's warnings to the outside Directors.

[16] Each state has template legislation implementing the same words but into their own jurisdiction.

[17] There are known as ARMCANZ Guidelines

covers these issues (Office of Regulator General Victoria, 1998), quality of drinking water supply, sewage effluent, water supply reliability, interruptions and restoration times, sewage service reliability, emergency telephone call response, licensee performance such as account debt, and customer service compliance with customer contracts.

### 5.1 Case study: SA Water, Adelaide, South Australia

SA Water was corporatised in 1995 and is subject to the *Public Corporations Act 1993*, which provides a framework for the commercial focus. SA Water's objective is to achieve commercial rates of return on assets after allowing for community service obligations. The EPA is the external regulator on water quality and was established the year before. SA Water provides services to metropolitan and country areas for water and sewage.

SA Water has a long-term contract with United Water for United Water to provide service delivery and maintenance of SA Water's metropolitan water systems under a fee-for-service agreement. SA Water retains ownership of the assets and maintains overall management responsibility for the water supply including the approval of all capital investment. SA Water also has the responsibility for facilitating the development of a viable export focussed water industry in SA. The target for net exports in 1996 of \$9.5 million was exceeded. (Steering Committee on National Performance Monitoring of Government Trading Enterprises, 1998). In 1999, SA Water contributed \$197 million to SA and United Water achieved a net export of \$50 million against a contract requirement of \$34 million (SA Water, 1999, p11). It was proposed to enable the public to buy shares but the terms of the contract have not been made public and no shares have been offered.

## 6. SUMMARY AND CONCLUSIONS

The legal instruments and regulatory models chosen in Australia are widely diverse as a function of inherited water regimes and insistent State autonomy. The Federal Government is still driving the direction of reform by financial incentives but each state has selected different mechanisms. This diversity is a strength as, once more pressures are put on the various systems, it will be easier to compare to select a better model and also better policies within the different models. At present, the legal instruments used are delegation of powers under acts of parliament with private sector bodies being able to accept these delegations. There is then a regulatory monitoring scheme in place. The National Regulator has been reported as describing regulatory monitoring scheme as patchy and the Sydney Water crisis also revealed inadequate links between components of the system. Nevertheless, the system has strengths and has been transformed very quickly. As yet, more time and experience is needed to determine the best approach on the multiple issue in the present scope of water reforms in Australia.

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# Water resources management in China: unsolved problems despite notable innovations and mammoth projects

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**Summary**
China has a number of unique climatological and topographic features which combined create immense problems for flood mitigation and drought relief. These have at various times been tackled on a grand scale and often with considerable innovation of approach and method and a sample of major water construction projects from different eras are discussed. With some exceptions the basic problems of water shortages in the north and of magnitude of silt transported by some rivers have not been solved and are in fact worsening. New problems of useable groundwater supply, on which most of the population depends, are appearing. The appropriate solutions appear to be better land use planning and control and pollution control, possibly coupled with more smaller-scale locally owned and managed rather than grandiose construction projects.

## 1. BACKGROUND FACTORS

### 1.1 Climate, Water Resources & Irrigation

To understand the special problems posed to water resources management in China it is necessary to appreciate some climate and resource factors. Total rainfall diminishes northwards. Wet rice cultivation is intensely practiced in the south. In the north the loess plains are very fertile - 64 % of China's arable land is in the north. The loess, whether in-situ or transported by flood, is well drained and rich in inorganic nutrients. It organic manure, but agricultural production is limited only by the availability of water. Irrigation is necessary in the north and the south and constitutes the major water demand component. Rainfall is also highly seasonal (some 80 % of total annual rainfall occurs during 3 months) and highly variable annually. For example during a 50 year period the July rainfall in Shanghai varied between 3 and 306 mm (Needham c). These factors affect flood patterns and requirements for quantity and timing of irrigation supply. North and north-west of the Great Wall annual rainfall falls below 375 mm and agriculture gradually gives way to pastoralism (Dwyer).

China's renewable water resources are estimated at 2,800 $km^3$/yr with 18% of this being consumed mainly (almost 90 %) for irrigation. However only 19 % of the total resource is in the north (and 126 million people live in an area of 426,000 $km^2$ with renewable water of only 52 $km^3$/yr (in Ilomäki).

### 1.2 Hydraulic technical development

As far back as Han the Chinese could supply water to elevated tanks with pipes and elevated aqueducts which were able to "...lead [water] up and down as if by magic" (Needham a). The Chinese also developed a variety of pumps including the double manually swung bucket, the shadouf, the hand operated scoop wheel, the square pallet chain (or "dragon skeleton water wheel", Tregear b) pump and the noria (see Table 1).

They made pipes for domestic water and irrigation supply from bamboo, earthenware and stone and also devised a variety of joints and fittings. The largest known ancient Chinese water supply systems were built in +1089 in Hangchow and in +1096 in Canton (Needham a).

**Table 1:** Technical Development (Source: Needham a)

| | |
|---|---|
| double hand-swung bucket | +1145 (or +1210) |
| counterweighted bailer (swape, shadouf) | +1145 (or +1210) |
| winch or drum with crank or capstan | +1313 |
| scoop wheel in flume, hand operated | +1313 |
| square pallet chain pump | |
| treadle operated | +1145 (or +1210) |
| animal or horizontal water wheel drive both via right angle gearing | +1313 |
| hand operated (for short lifts) | +1637 |
| High lift noria and pot chain pumps (current driven and animal driven via right angle gears | +1313 |
| High lift pot chain pump, driven by horizontal water wheel via right angle gearing | +1609 |

## 2. ELEVATED RIVERS

China is dominated by its large rivers, principally the Yellow, Yangtse, Huai, and Pearl, all subject to sudden rises due to the seasonal rainfall. They pick up heavy sediment loads while descending from the mountains in the west and emerge onto the plains with water and silt invaluable for agriculture, but also with threats of flood.

### 2.1 Yellow River

A prime example and a case of a problem still not solved is the Yellow River which has plagued China for a very long time. The river is some 4600 km long and has a catchment of some 600,000 $km^2$ (not including some 154,000 km$^2$ of plain traversed by the river, but effectively lying below the river, Needham c). In the upper catchment it flows through easily erodable loess soils, the area which is the cradle of Chinese civilisation, where it picks up a huge silt load to become the siltiest river in the world, washing some 2 billion tonnes of sediment towards the sea. Emerging onto the north China plain, the river then falls less than 0.2 m for the entire 800 km course to the sea (Harland), thus allowing the silt to deposit. Embankments or dikes which were constructed for flood protection (and had to contend with flows of 28,300 m$^3$/s, Needham c) contained the deposited silt, so raising the river bed. To maintain flood protection the dikes have had to be raised as well.

Although Emperor Yu, founder of the Hsia dynasty ca. -2205 (Dwyer) is popularly credited with controlling the Yellow River by first introducing dikes (and irrigation canals) (Dwyer, Harland), the process of rising bed and dikes began as long as five to eight thousand years ago (Harland). Protecting the banks and repairing breaches was enabled by the invention of the sao. This was a roll of layers of grass and timber wrapped around earth and stone and tied together with ropes of grass and split bamboo. The whole, measuring several chang high and double that in length when rolled up, was manoeuvred into place by large teams of labourers with ropes (Yang).

Periodically dikes have burst or been overtopped. Some 1500 floods and 26 changes of course have been recorded since the Han dynasty. The threat of flooding following an embankment collapse becomes progressively more dangerous as more of the river flows above the plain. An appreciation of the consequences of a flood can be gained from the last major flood from the intentional breaching of the banks at Huayuankou ridge by Nationalist troops in 1938 (Harland) which killed a million Chinese, flooded some 54,000 km$^2$, forced 12 million people to flee their homes, and changed the course of the river to enter the sea 700 km further south than previously.

This process of rising river bed and dikes is still continuing, actually at an accelerated rate caused by increasing erosion rates due to catchment clearing and agricultural activities. The bed has been rising some 0.1 m/yr and the river now enters the sea some 25 m above plain level (Harland). Recent projects to control the Yellow River, as with the dam completed in 1960 at Sanmenxia with a capacity of 8000 GL, have not been successful. The design of this dam appeared to disregard silt loading and has had to be re-engineered. It now has a third of its design capacity, drastically reduced effectiveness for flood prevention, power generation and irrigation storage (Pearce). Undeterred the government planned to proceed with a further 30 dams on the Yellow River (Harland) despite these projects not expecting "to have a long useful life" (LEUNG). So far the Tianqiao run-of-river power plant is completed and Wanjiazhai (see below) is under construction.

In much of northern China, growing demand for water from industry and cities is diverting more of the Yellow River's water at the expense of agriculture in the lower reaches of the basin and has, however, already begun to run dry (consumption of northern rivers exceeds 60 % of annual flow, in Ilomäki). The worry is that the Yellow River may soon fail to reach Shandong Province where it supplies half of the irrigation water to produce 20 % of China's corn and 15 % of its wheat (the remaining irrigation comes from groundwater that is falling 1.5 m/yr) (EDIE a). The river first ran dry in 1972 when it did not discharge to the sea for some 15 days. It ran dry in some years until 1985 and then every year for part of the year after that. In 1997 it failed to reach the sea for 226 days and for much of that year even failed to reach Shandong.

**2.2 Yangtse River**

While the name Yangtse (Yangtze) commonly (and in this paper) refers to the whole river, it properly applies only to the last 500-600 km of its course, the region of the Yang kingdom of about -1000. In its upper reaches it is called the Jinsha (Chin-sha, Golden Sand) and other names are applied elsewhere. The whole river is called the Chang Jiang (Long River).

The Yangtse, too, poses a flood risk in its middle and lower reaches where some 40 % of China's industrial and 35 % agricultural production is located (Zhang). In 1931 the city of Wuhan was flooded for more than 100 days resulting in 145,000 deaths (Li) and another major flood occurred in 1954. By comparison, the 1998 flood, which in places was over 10m higher than in 1931, did not breach any "main" dikes (Li). While less rain fell than in 1954, water levels were higher due to siltation which had been raising the river bed by 0.1 m/yr (Zhang). The toll was still 3000 deaths, 4 million displaced and 1.3 million houses and other buildings destroyed (EDIE b, Lawrence a). The relative success was ascribed to improved dike engineering and to "1,129 large and medium sized reservoirs across the country [which had] detained ... 33.4x10$^9$ m$^3$ water" (LI) and to the emergency efforts of over 8 million citizens (Zhang). Future flood patterns will be further affected by the Three Gorges project. New efforts are also underway to improve critical dike infrastructure on the Yangtse (EDIE b). Australian input in flood modelling is included (Menser).

**2.3 Minjiang River.**

By contrast, the Minjiang River in Sichuan was successfully harnessing for irrigation as well as for flood control in -221 (Tregear a) and the project remains the basis of the existing irrigation scheme on the Chengdu plain. Not only was the scale of the project huge, involving the 20m dia Baopingkou ("Treasure Bottle Mouth") tunnel through Mt Yulei (Guanxian county) and two irrigation diversion weirs, but it was also innovative in a number of ways. One weir, Dujiang dam, was of the "fish mouth" type, built parallel to the current with a pier pointing upstream to bisect the river. Another, Feisha dam, was built with a long spillway along the diverted stream to return flood flows to the main stream. Construction during flood was achieved by placing rocks held together in large bamboo baskets 10 m long x 600 mm wide, the forerunner of modern gabions. The rock was tunnelled without iron tools by cracking it by heat from fires made in grooves worked into the rock. The project was supervised by Li Bing who is credited with pioneering these construction techniques and with instituting a scheme of dredging which required the annual construction of a coffer dam (Chai).

## 3. INTER BASIN WATER TRANSFERS

A number of major projects to transfer water to the dry north have been constructed or are being planned. The source of most of these transfers is the Yangtse, the world's third largest river in terms of total annual discharge (average some $1 \times 10^{12}$ $m^3$, Costin & Frith).

### 3.1 Grand Canal

The first such transfer was enabled by the construction of the Grand Canal, now some 1900 km long, during the Southern and Northern dynasties +420 to +618. There is conflicting opinion whether the intended purpose was for water transfer (Needham c) or transportation (Dwyer).

### 3.2 Yangtse Diversions

In recent times the canal has been dredged and equipped with pumps specifically for water transfer (Harland) and is now regarded as basis for the eastern of three links for water transfer from the Yangtse to areas north of the Yellow River. The overall plan, which was first proposed by Chairman Mao in 1952, would divert up to 4800 GL/yr and has aroused concern about its merits and potential environmental impacts (AAP, EDIE d, BBC).

The first stage eastern link project, to divert 16 GL/yr from the Yangtse into the Yellow River, particularly for irrigation in Hebei province, Beijing and Tianjin and for improved water supply for the Beijing Tianjin area and 32 other cities (World Water d), is set to begin early 2002. The project includes a 9 m dia tunnel some 60 m under the Yellow River, 2,400 km of channel and 18 major pump stations.

A central link from Danjiangkou (on a Yangtse tributary) to Zhengzhou on the Yellow River, and a western link through some of China's most mountainous terrain in Qinghai province where the headwaters of the two rivers are separated by only some 100 km (World Water b) are also proposed. Further investigation is needed for the difficult western link.

### 3.3 Luanhe to Tianjin Link

On a smaller scale, although at the time of building still ranking third amongst China's modern water projects in terms of investment, land area and labour input, 60 kL/s is being sent 234 km south to Tianjin from the Luanhe river. The route includes a 12 km tunnel constructed in 1982 by 12,000 soldiers and a 50 km canal dug by 120,000 "volunteer" residents of Tianjin (Deng & Liu).

### 3.4 Wanjiazhai Yellow River Diversion

Currently China's second largest water project is underway to transfer 1400 GL/yr (including 200 GL/yr to Inner Mongolia) via 220 km of tunnels and a series of pump stations for irrigation and municipal consumption as well as to generate power (Lawrence b, China). Although some components of the project have been commissioned, it is too early to judge the environmental soundness of the design.

## 4. WATER SUPPLY

Much of the rural population, especially, has relied on shallow dug wells and less frequently on shallow tubewells for domestic water supply. The wells were constructed by lowering a timber frame of about 2 m dia on which was built a brick lining (Smith). Stoneware well linings, about 1 m dia and 0.5 m long dating back to -3rd century have also been discovered at Hsienyang, (Needham a). Lining was used from early times to prevent collapse of dug wells in the unstable soils. Double windlasses or sweeps were used to draw the water. It is interesting to note that the bucket, ropes and even windlass were taken home at night for security (Smith). From a public health point of view these supplies could not be considered safe as any protection such as a cover or a wall was rare. Although wells were not places for human ablutions, animals were watered there and the surrounding ground was usually very muddy (Smith).

Present usage of shallow groundwater is still high. About half of the major urban centres rely on it for water supply. Groundwater represented 65 % of consumption for Beijing and 46 % for Tianjin in 1984 (East-West Environment and Policy Institute, World Water b). In north eastern Shandong province more than 155,000 new wells were reported to have been dug (Canberra Times). Overpumping has occurred in many of the cities (World Water b) and this is particularly true of the northern areas (Harland) including Beijing and Tianjin. Water in Tianjin has become brackish and consumption restrictions have had to be enforced, even on industry (Deng & Liu). In Beijing the groundwater level has dropped over half a metre in one year (World Water a). Water tables are dropping "precipitously" and rivers in north China are containing less and less water (UNDP). Significantly, a 1986 study found that the groundwater of most of the provincial centres is now polluted (World Water b).

The present research has not elicited any records of Chinese use of deep groundwater. The absence of early deep wells may be due to a lack of appreciation of hydrogeology as indicated by the belief "the deeper they went the more there wasn't any water" (Smith). There was also a superstition, at least in later Han times, that digging wells might hurt the "veins" of the earth, an offence deemed capable of bringing misfortune on the diggers as well as on their neighbours. Nevertheless, many shallow wells were being dug as evidenced by a large number of pottery models excavated from tombs of that time (Yang).

The Chinese possessed the technology of deep drilling as early as the Early Han. Bores sunk to tap brine and natural gas, particularly in Sichuan, were up to 600m deep (Dwyer, Needham a). The brine was raised with bamboo tube buckets. These were some 25m long and 75 mm dia with a leather flap valve at the base for filling. The buckets did not form a seal against the bore casing although the potential for use of such an arrangement for pumping was realised in the case of air bellows. Piston pumps for liquids were not common Another Chinese invention whose principle may have contributed to the development of a bore pump is that of the syringe or "water gun" (described +1044) which was made for military purposes from a bamboo barrel and silk floss to provide a piston seal. It has been conjectured that the Chinese may have used such a device as a suction lift pump for the water supply of Loyang in +186. However, application of the principles of the syringe and of the valved water bucket to water pumping was ultimately left to Europeans (Needham a).

Some 40 % of China's rural population, itself 80 % of the total population, does not have access to water of adequate quality. Their water supply is either untreated surface water, has excessive fluoride content or is too brackish. To overcome this huge deficiency some innovative design methods are being employed, such as that of providing supply only during limited hours when people are less likely to use the water for other than domestic use. For rural systems the design levels of service are 45-80 L/c.d for 70% of population with house connections supplied during a 6-8 hour supply window, and 20-40 L/c.d for the remainder served by public water points consisting of hand pumps or rainwater systems. Surface supplies are to be given conventional coagulation, filtration and chlorination treatment (World Water c). Nevertheless even the targets set for 1990 as part of the UN International Drinking Water & Sanitation Decade, catered for only half of the people in need.

Of China's 668 cities, some 400 are believed to suffer from water shortages (EDIE d).

Besides water availability, the quality of water is also a problem. *A recent study found that most rivers suffer from "severe and widespread pollution", a cost paid for China's rapid economic development. In particular, more than 90% of surface water in China's urban areas is "seriously" polluted (UNDP). A World Resources Institute study has found that some 700 million Chinese consume contaminated water (EDIE c)* . Only one fifth of industrial wastewater is treated in some way before being discharged into the watercourse (in Ilomäki) while continued industrial expansion is all the while increasing waste loadings on surface and ground waters. The Word Bank has warned that "challenges to ... environmental protection remain, and need to be addressed to ensure continued development success".

## 5. THE GREAT LEAP FORWARD

The Great Leap Forward saw a change in the type of major water projects and in their method of execution. Whereas the first few years after liberation had seen the continuation of a relatively small number of very large projects (including those under the First 5-Year Plan 1953-1957 executed with USSR assistance, Chi), policy changed in 1957 to give priority to "... small irrigation projects, secondarily, medium-sized ones, and large projects for water conservancy only when necessary and feasible" (Chi). Additionally, projects in the ensuing few years were required to emphasise water storage and construction by the communes. As a result, with slogans such as "Let Tens of Thousands of Rivers and Mountains, the Great Jade Emperor, and the Dragon King Take Orders from Us", at least $70x10^9m^3$ of earthworks and masonry were completed in the period 1950-58 (Chi). 100 million people were mobilised in the first year of that policy.

The overall result in terms of drought relief or flood protection were however hardly satisfying. Drought and flood episodes which had affected $7\text{-}13x10^6$ ha each year during 1934-37, and 43 and $60x10^6$ ha in 1959 and 1960 respectively. While theoretical achievements may have been high, it turned out that "...some of the reservoirs have no water...[or]...contain water but have no aqueducts, and the land surrounding the reservoirs is still in need of more construction..." and many projects were thus unable to be utilised in part or in full. Moreover many hastily built schemes, often built against the advice of local technical experts, contributed to raising the water tables and so to increasing soil salinity and alkalinity, so making the soils useless for agriculture (in Dwyer), particularly in susceptible areas such as North Kiangsu, Hopei, Shantung, Shansi and parts of Manchuria. There were also many cases of dams collapsing (Chi).

Only in 1963 did policy change to emphasise improvements in efficiency of existing irrigation projects by better management and "fitting-out" such as by adding aqueducts to allow an already constructed storage to be utilised (Chi).

This era was also infamous for destruction of natural resources, including much clear felling of timber (Huus) which exacerbated sediment and flood risks.

## 6. DAMS

An early dam was Fushan dam on the Huai River, built to block passage across the Huai during an attack against the Wei Kingdom in 516. Its scale and sophistication were unprecedented, but four months after completion it was overtopped and 10,000 people were killing. Since then the number of large and medium sized dams has grown from a 1949 total of only 23 to more than 80,000. Official enthusiasm rather than good design and construction characterised many such dams, particularly during the Great Leap Forward and shortly afterwards. By 1981 the number of formally recognised dam collapses reached 3,200, including the Shimantan and Banqiao large dams with a combined death toll of up to 230,000. Two "key" dams constructed on the Yellow River during the Great Leap Forward have been dismantled (Shui).

### 6.1 Three Gorges Project

Sun Yat-sen first proposed a Three Gorges hydroelectric dam in 1919, but the plan was shelved due to the political and economic conditions. Then, following the 1954 floods, Chairman Mao ordered feasibility studies (Kennedy) for the dam for flood mitigation. Since then the dam has been debated, initially over cost and engineering issues, and more recently over its environmental impact (Huus, Probe International). In 1991 citizen pressure forced a suspension of the plans, but approval was given in 1992 under prime minister Li Peng. Construction started 1994 and completion is due 2009. Chongqing (Chungking), capital of Sichuan Province, was excised as a municipality in 1997 and put under the direct control of the central government for this project. After some financing problems, the project received priority following the 1998-99 floods (US Embassy). Construction of a channel for the complete diversion of the river is now complete and Phase II is in progress (Gifford, Sklar).

With a crest height of 185 m and 2,000 m long and impounding a lake 600 km long, the Three Gorges Dam at Sandouping will be the largest hydroelectric dam in the world. It will have a total storage capacity of 39,300 GL with 22,100 GL set aside during the May-September flood season for flood control (IRN, Leopold)

Internationally the project has been largely condemned for the impact, with both the World Bank and the US government refusing support (BBC b, IRN). Impacts include inundation of over 100 towns as well as some of China's most fertile land, displacement of 1.2-1.9 million people with 100,000 having already expressed dissatisfaction with their allocated destinations. Some 1,300 archaeological and historical sites, including remnants of the homeland of the Ba, who settled in the region about -2000, will also be drowned (Wu, Kennedy). There are also fears for impacts on historic Chongqing, and for the survival of the snub-nosed dolphin and the Siberian crane. (BBC). There is also debate over the claimed fiscal costs and benefits, and whether the flood protection might be more economically achieved by alternative means (Kennedy).

There is concern over the untested assumptions, at least at comparable scale, of an ultimate (70 to 150 years hence) stable and uniform slope sediment profile under the proposed operating procedure; compounded by the overwhelming history of sedimentation in China's large dams, and the logic of sediment flushing without flood damage (Leopold). Flood-control benefits will be limited also since the dam is upstream of several large tributaries (US Embassy). Technical concerns include rock wall instability, sedimentation of the diversion channel and safety of the Phase II coffer dam (Sklar). Further concerns relate to shoddy construction and dam safety (Kennedy)

## 7. CONCLUSION

Evidence of a sample of major water construction projects shows that a number of these have not been able to provide long-term provision of flood control or drought relief. Some hastily conceived projects have even exacerbated the situation. The main problems appear to be the water shortages in the north, and the magnitude of silt transported by some rivers. The water shortages have resulted largely from increases in irrigation and industrial demand, a manifestation of inefficient resource demand allocation (East-West Environment and Policy Institute). Excessive siltation is being generated by some agricultural activities in susceptible parts of the catchments. In both cases effective land use planning and control would provide more long-lasting and economical solutions than the extremely expensive heavy construction projects. In addition pollution control measures are required to protect existing shallow groundwater.

While possibly anathema to leaders remembering the follies of the Great Leap Forward, more smaller-scale locally owned and managed storage and flood protection schemes might be a far more sustainable solution than the grandiose Three Gorges project. Only future generations will be able to pass final verdict on the price paid for the development attained.

Some signs of hope for sustainability can, however, be seen in the central government in 1998 banning logging in the upper Yangtse catchment; in its admissions of poor past practice (particularly Jiang Zemin's speech that September admitting that the government had too often tried to impose its will on nature and calling for "coordinated development of the economy and ecological environment" and for water conservancy projects, Lawrence a); and in successes in demand management and industrial water recycling (for example in Taiyuan, Shanxi, average consumption was reduced to some 25 L/c.d and industry recycled 84% of its water, Lawrence b)

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# Early water development at Arltunga Goldfields (Central Australia) by South Australians

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**Summary**
This Paper will discuss the first intensive development of groundwater at Arltunga and the mining limitations associated with water shortages. Arltunga was situated 97 kilometres east of Alice Springs and experienced the first gold rush in the Northern Territory in 1887. The field was located in a remote and destitute region and the route to the field was a largely waterless, desert track. The South Australian Government took responsibility for the Territory in 1863 to primarily construct the Overland Telegraph Line and to expand its pastoral empire. It was these two European industries which first "opened up" the Territory and encouraged settlement and enterprise, and initiated water development. Even though water supplies were first augmented to meet the needs of pastoralism and communication, it was the need to mine gold which intensified groundwater development.

At the end of the rush in 1905, Arltunga had not only provided revenue for the Government but knowledge of Central Australia's groundwater had been increased. The skills that early well sinkers acquired at Arltunga were later utilised on pastoral properties, other mining fields and on future settlements. The irony here, was that the ambitious economic dream which the South Australian Government had for its northern colony failed. On its transfer to the Commonwealth in 1911, the Territory had, instead, left the South Australian Government a huge debt.

## 1. INTRODUCTION

*The one thing absolutely necessary for the immediate prosperity of South Australia is a vigorous and systematic opening up of its magnificent auriferous country...in South Australia proper and its Northern Territory.*

This Paper will discuss the first intensive development of groundwater at Arltunga and the mining limitations associated with water shortages. In doing so, a small glimpse into the lives of those miners and well sinkers who lived and worked under such adverse conditions will be captured. The initial two industries which "opened up" the Territory and encouraged settlement and enterprise were communication and pastoralism. While water supplies were first augmented to meet the needs of the Overland Telegraph Line and pastoral properties it was not to be either one of these industries which would spur and hasten water development in a centralised region. Instead, groundwater development was motivated by an unlikely source, a gold rush in the middle of nowhere. Arltunga, 97 kilometres east of Alice Springs experienced the first gold rush in the Northern Territory in 1887. The field was located in a remote and destitute region and the route to the field was a largely waterless, desert track.

The inability to develop adequate water supplies was one of the underpinning reasons why between 1824 and 1849, three British colonies on the Territory coast were abandoned. Although these settlements were situated north of Darwin in the tropical region, they still suffered from surfacewater shortages and barren wells during the dry season. After the failure of the British to permanently colonise the Northern Territory, South Australia took responsibility for the Territory in 1863 to primarily construct the Overland Telegraph Line and to expand its pastoral empire.

The development of the Northern Territory's water resources was driven by the South Australian Government's need to make its northern colony profitable. Behind the scenes were the pastoralists and miners who dreamed of discovering their own private Eldorados. Miners, in particular, needed water for sludging, panning and for the operation of batteries, not to mention domestic uses and watering stock. For those miners who made the pilgrimage to Arltunga, the field offered a foreign and harsh environment with no facilities, supplies or infrastructure. The discovery of gold and the subsequent "rush to nowhere" not only assisted the South Australian Government in its quest to profit from Territory minerals, it also changed the direction of water development to meet the requirements of the mining industry. Intensive water development in a defined area made a significant contribution to the beginning of the Territory's groundwater information base.

## 2. MAIN BODY OF PAPER

The Northern Territory presents unique challenges to water resource managers because it covers an extreme range of climatic zones within an extensive geographic area. Similar climatic extremes are only found in places such as Western Australia, Queensland, Western Africa, Angola, and north west India/Pakistan. The Territory has two climatic zones; the tropical zone and the arid zone. The tropical zone, commonly known as the "Top End" covers the north of the Territory to Daly Waters in the south, while the arid zone encompasses the south to the South Australian border. Surfacewater is scarce, unreliable and subject to high evaporation which is why the arid region has always totally relied on groundwater. Rainfall can range from zero to 350 mm during the summer months or from zero to 250 mm during the winter. Potential evaporation is extremely high, much higher than rainfall, averaging three metres annually.

Groundwater development became fundamental to settlement, and the mining and pastoral industries of Central Australia.

Credit is due to the young South Australian colony which acquisitioned an unproven and virtually unexplored territory. Adelaide itself had only been founded 27 years before it acquisitioned the Territory but by 1866 Adelaide had a population 54,000 with another 56,000 people dispersed throughout South Australia. Adelaide had to also deal with the tyranny of distance in governing a far-flung colony. Darwin was 3000 kilometres and Alice Springs 1500 kilometres to the north. Against such odds, South Australia's progressive settlement and development plan in the form of pastoral leases, and the Overland Telegraph which followed John McDouall Stuart's footsteps soon came to fruition. The many wells which were constructed at the repeater stations not only supported Telegraph staff, but also provided water for miners, pastoralists and others who journeyed to the Territory.

Early descriptions of water resources by explorers and other travellers to Central Australia varied, and often contradicted each other. Reports were generally enthusiastic about the potential of the region for grazing and mining, while others such as John Forrest called Central Australia miserable *and intolerable*. Major Warburton described it as *terrible*, Alfred Giles said it was *frightful* and George Windsor dubbed it *the general sterility of Australia*. Information regarding water resources ranged from waterless to abundant, depending on what time of the year the person travelled, and if drought conditions were present. Generally, most visitors were naive to the hazards that such an environment could present. Robert Frearson wrote in 1903, that during *my trip to the fields splendid rains had fallen, and an abundance of water and grass was to be had. Most of the rivers, creeks and clay-pans had water in them*. It was obvious that Frearson travelled during the best time of the year and neglected to add that most surfacewater was not permanent and would disappear soon after the rains ceased. Frearson, among many others at the time, were ignorant of Central Australian conditions and it was an irresponsible statement to publish.

## 2.1 THE ARLTUNGA GOLDFIELDS

*Capitalists are beginning to be aware to the fact that the MacDonnell Ranges are richly impregnated with gold...*

Not only were declarations like the one above frequently mentioned in newspapers and reports of the day, but such exaggerated accounts would have evoked tremendous interest in Arltunga. A vision of another "Ballarat" would have inspired many to make the perilous route to a mining field situated in a desert. Those who could afford it began the journey by rail - from Adelaide to Oodnadatta it was a 1032 kilometre journey, and from Oodnadatta it was overland on a

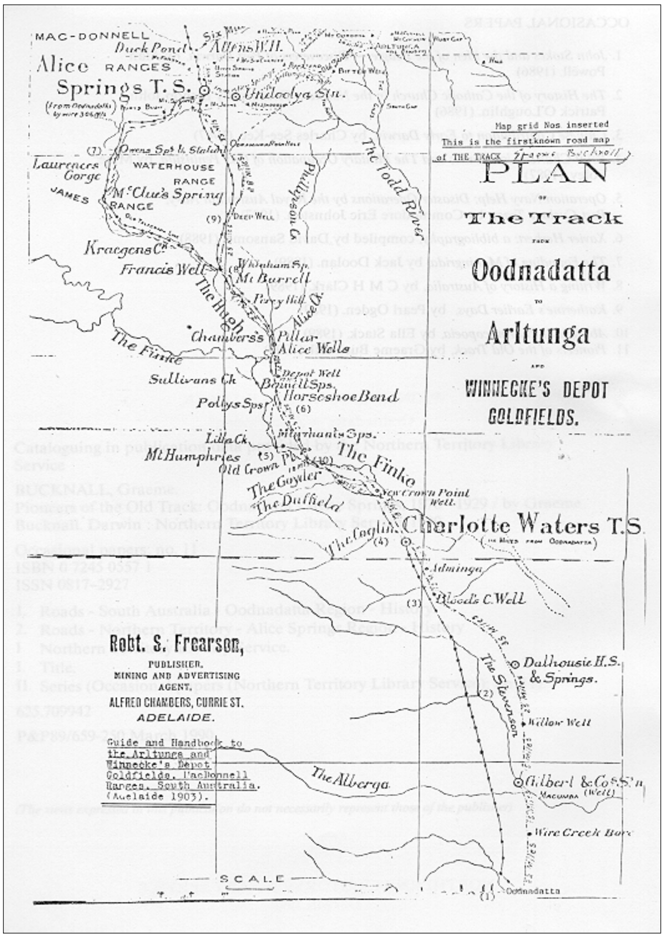


**Figure 1:** The track to Arltunga. Frearson (1903)

622 kilometre beaten, almost waterless track to Arltunga. At the time, the Northern Territory's European population was 200 with less than 50 people living in Alice Springs. The township of Alice Springs consisted of a telegraph and police stations, three general stores, one hotel and a saddler's shop. Prior to the rush, the only Europeans to visit Arltunga were the odd explorer or stockman. All food and supplies for the goldfield had to be overlanded from Oodnadatta, which took about three months for a round trip.

Paddy's Rockhole was the initial water available on the field and as expected, this was where most of the mining population congregated. Not only was the rockhole utilised for drinking, watering stock, washing and panning, but water was also collected from it and hauled to other claims on the field. Overuse soon contaminated the rockhole and it eventually dried out.

Geologists were scarce until the Commonwealth Government established a Territory Water Use Branch during the 1950s that was dedicated to water development. Until then, the selection of well sites was usually judged by the experience or guesswork of the driller who were usually water diviners or reef miners. One early driller commented*: We would look for a crop of sandstone or limestone in the rock formation to drill a bore*. Until the formation of the

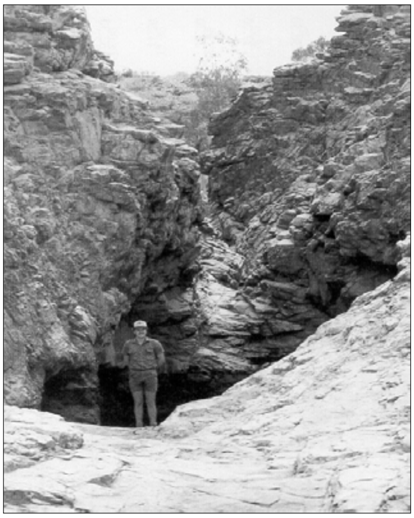

**Figure 2:** Paddy's Rockhole. Mackie (1986)

Water Use Branch, the Territory only had access to visiting geologists. Government Geologist H Brown was to be Arltunga's "resident" geologist throughout the rush, visiting at least annually. Brown was first sent to Arltunga by the South Australian Government in 1888 to assess the field's potential. He was immediately concerned about the lack of water on the field and pressured the Government to initiate a groundwater development program. Of most concern to Brown was the plight of the miners and the limitation of the field because of water shortages. It was imperative that the field succeed as a revenue raiser for the Government as the Territory had not even begun to pay its way.

Obviously Brown's advice was heeded as the first well at Arltunga was completed by the end of 1888. A second at Paddy's Rockhole followed in 1890, which coincided with Brown's next visit. Although the two wells were producing water more was need. Brown urged the Government to increase the supplies to keep pace with mining. He was especially adamant on this point, as some miners were still forced to transport water to their leases and water was costing them a 5th of their gold findings. In his report to Government, Brown stated that the water shortages were having a detrimental affect on the industry; miners had two choices; either pay for water to be delivered or to carry out "dry blowing". "Dry blowing" was a less efficient method as this limited the amount of gold which could be found. The "dry blowing" method only treated surface gravel, sand and silts and could not reach the deeper underlying clay where most of the alluvial gold was located.

A major hindrance to well construction was the inability to attract well sinkers to the Territory. Wages were not exceedingly high and men had to work under difficult conditions for long periods in the remotest regions of Australia and suffer the hardship of being away from families. It was not uncommon for wells to take up to 12 months to be manually dug, a major undertaking that tested the skills, determination and endurance of these men. Accommodation consisted of tents that offered little protection from extreme temperatures that could range from zero in the winter to 45 C in the summer. Equipment had to be transported by rail from Adelaide to Oodnadatta, and from there by horse, camel or donkey teams on what was little more than a rough bush track to stations or the mining fields. Most wells were sunk in regions to where materials, water, food and equipment had to be carted over hundreds of kilometres. This was not a simple task when considering the menagerie of chickens, milking cows, goats and turkeys that had to travel with the consignment.

One notable well digger, employed by the South Australian Government was Ned Ryan who became renowned for his ability to find water in the most destitute areas. Ryan used a camel team to move his equipment from site to site that earned the title "Ned Ryan's Camel Party". Ryan had dug wells for the Overland Telegraph Line and stock routes from 1885 until 1890 when he was sent to deepen and improve Arltunga's first well.

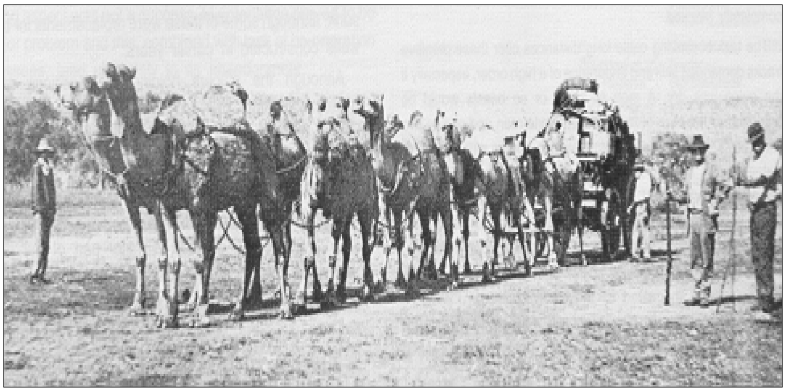

**Figure 3:** Government Well Sinking Party. Hare (1985)

Ryan initially based the construction of his wells on British designs on Figure 4 but needed to vary the method depending on the conditions and strata he was working with. Without easy access to equipment and materials, Ryan obviously tried to keep well construction simple when he commented that *the mere excavation of a well requires but little skill, the plumb-bob and rods cut to length being sufficient to ensure accuracy; but at times it is a matter of great labour necessitation the blasting of hard rock. Buckets, a windlass and ropes are required to remove the products of the excavation.*

The construction of a well at Arltunga required ingenuity and the need to modify the well to suit local conditions. In such difficult strata as Arltunga, the excavation of the well would stop once water was struck, but over a period of time, the water level would gradually drop making it necessary to continually deepen the well. By the end of a well's life, it usually had been sunk much deeper than the considered safe

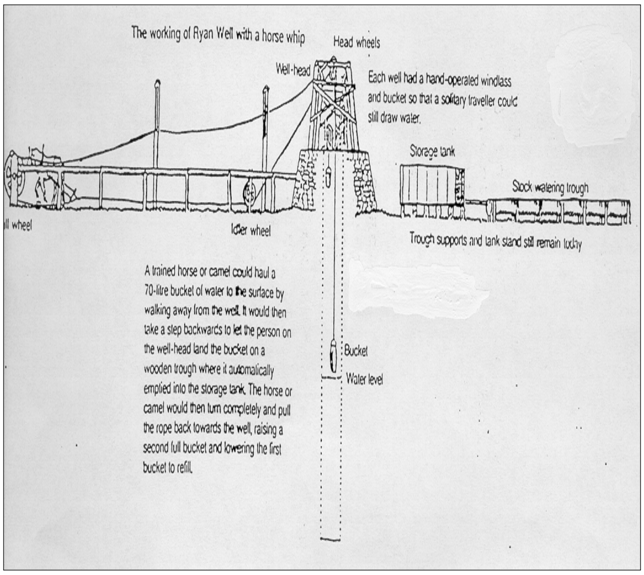


**Figure 4:** Ryan's Well, named after Ned Ryan
Ryan (1991)

depth of 50 metres. Other differences were the timbering of wells. While most Australian wells were timbered throughout, it was an expensive and time consuming process in the Territory, so only the unconsolidated portion of the well was timbered. The well was lined with whatever timber was available, which, in Central Australia, was mulga and river red gum. The lack of timbering was also attributed to the effort required to hand saw the timber. A back breaking job especially inside a hot and unventilated pit. With the lack of water, most well excavation was carried out dry, making it a more painstaking task for the diggers who had to inhale quartz and saw dust.

Northern Territory wells measured approximately two metres by one metre, making it wider than traditional wells. A wider well made it a little easier to dig and pick or to drive the pins with sledgehammers. Well levels also had to be raised above ground level to prevent periodical flooding entering the well shaft, which could cause it to collapse.

By 1892, Arltunga could boast to having five wells, Kangaroo, Munday, Wheal Fortune, Claraville and No.1 (Muller's). Brown considered that the wells were in fair condition and could supply a reasonable amount of water for the population. Claraville was supporting several stores at this time, and a warden's office was built in 1895, followed by a police station in 1899. However in 1897, the Claraville Well was almost dry at 55 metres and could not supply the minimum 4500 litres per day needed for the Government battery. The low water supply forced the dismantling of the buildings, store, blacksmith's and battery and their relocation 11 kilometres away at the Star of the North Well. Figure 6 shows the Government Battery at its new location.

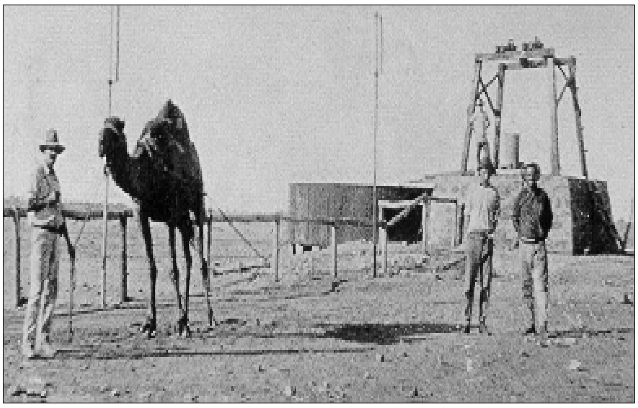

**Figure 5:** A camel powered "whip" well.
O'Byrne (1993)

Even though well construction was ongoing, the water supply could never keep up the demands of miners, small businesses, stock and the battery plants.

In 1898, a petition with 31 signatures was sent to the Government demanding that the water supply be increased. Demand for more wells would have also been fueled by Warden Mueller report that some 45 kilometres to the east, there were richer gold reefs, but without water they could not be exploited.
In February 1899, the Government sent Sam Olsen to sink a new well at White Range. The excavation of this well became a laborious and lengthy process. After 17 metres and some four months, later the well was only producing 180 litres per day. Further digging took place in mid 1900, which deepened it to 34 metres, but the volume of water did not increase. Finally, after a further nine months the well depth reached 49 metres but only managed to provide 540 litres per day. After such an arduous task, Brown would have been disappointed to have had to report that *only with careful usage, [the well would] supply the present number of men with water for domestic purposes*.

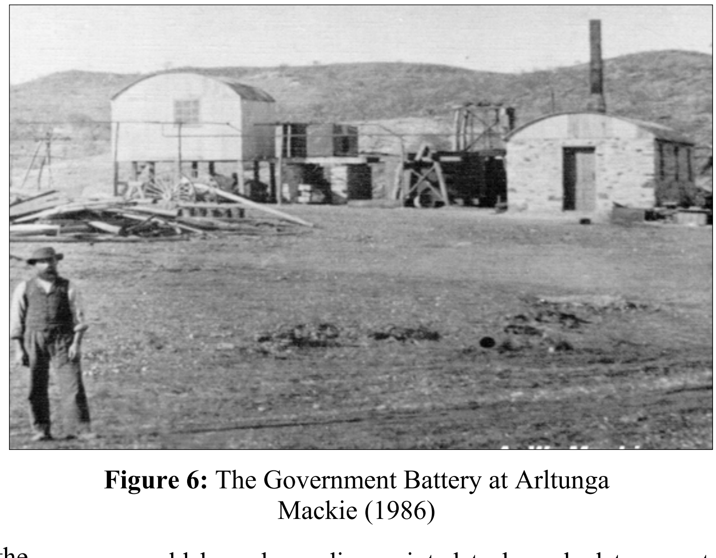

**Figure 6:** The Government Battery at Arltunga
Mackie (1986)

Despite Brown's energetic and heartening efforts to increase water supplies, shortages remained a constant problem that was still not resolved when the rush ended in 1905. Admittedly, for most of this period, the miners had to also contend with a severe drought that ravaged Central Australia from 1896 to 1903. The drought had affected all the wells at Arltunga, and had limited mining activities including the Government Battery, which eventually had to substitute its horse teams with camels. Regardless of drought conditions, water shortages at Arltunga were well recognised prior to then. Paddy's Rockhole which was considered a reliable source of water, had dried up in November 1888 and work on the field had stopped as the miners waited for rain.

With the continuation of the drought and water shortages, construction on another well began in May 1902. This was to be the most difficult and challenging well on the field. Initial excavation was good with 17 metres dug by August 1902 and work continued steadily until the contractor John Byrne *caught a chill when coming out of the well and he over-heated* and died in January 1903. In October 1903, well sinkers Sutherland and McKillop continued with the excavation but by December 1904 had only reached 34 metres. New tenderers, Dupon and Schaber continued the work and completed it in June 1905. The well was finally dug to 84 metres but found to be dry.

The largest number of miners on the field at one time was 400 in June 1903 and this put a great strain on the water supply. The water became contaminated in 1903 and a typhoid outbreak followed, resulting in several deaths. Water had to be carted in and the miners sent another petition to Government urging a new well to be built.

In 1905, another well was completed, but it probably wasn't needed as by September 1905 there were only eight miners left on the field. Ironically, when water became more available most miners had moved to new claims such as Harts Range further north, and the same water problems were repeated there.

## 3. CONCLUSION

Although the gold rush had ended at Arltunga, mining continued spasmodically with the numbers of minters never rising above eight. The field comprised an area measuring 18 X 36 kilometres and at the end of its era in 1905, nine attempts had been made to implement groundwater supplies. Considering that at the time, Alice Springs had no public well whatsoever, the efforts of Government to augment groundwater under such hazardous conditions should be commended. Until the late 1970s the only official description of these wells remained in Brown's Reports but now well logs and water analyses of these wells have been added to the Territory Government information base. Most of these wells have collapsed because dry rot or white ants have destroyed the timber frames. Analyses taken some 80 years later reveal that the water supply had a high salt content. If this were an indication of what the miners had to drink, dysentery would have been a continual health problem as according to the Australian Water Quality Guidelines for Fresh and Marine Waters, only one well was fit for human consumption.

The Arltunga Goldfield not only provided revenue for the Government, it also initiated the first intensive development of groundwater in one centralised area. At the end of the rush, the Government had become much more knowledgeable about the groundwater supplies of Central Australia. Besides this, Territory conditions demanded varying methods of well construction. Wells were usually made deeper, and structured and timbered differently. The experience that these early well sinkers gained were later utilised on pastoral properties, other mining areas and future settlements. Well sinking remained a vital and essential skill for the development of Central Australia until the Second World War when boring rigs became more accessible.

## 4. ACKNOWLEDGMENTS

A grateful thanks goes to Graham Ride, Gary Holmes and David Hardy of Department of Lands, Planning and Environment in Darwin and Alice Springs for their assistance.

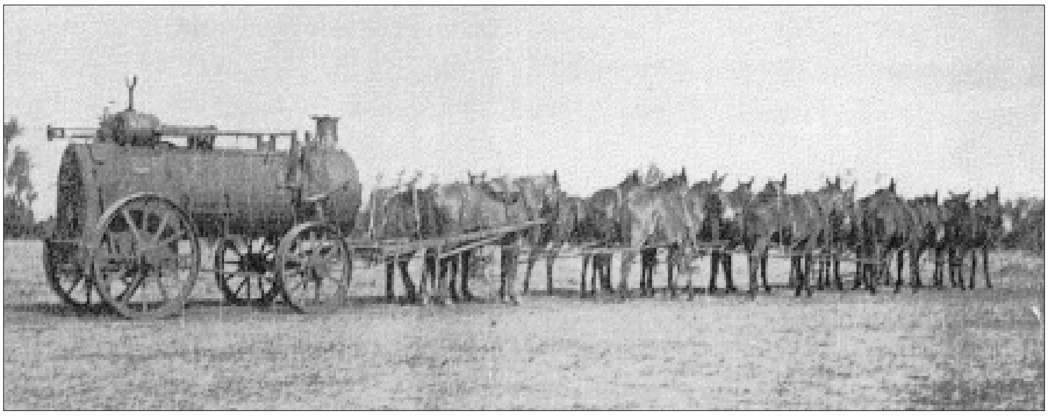

**Figure 7:** An early boring engine, 1918.
Makin (1976)

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# Water across Mitcham, South Australia

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**SUMMARY**
This work is a study of a small part of metropolitan Adelaide, but would be reflected across the region. It takes the reader from early settlement between Mitcham and Coromandel Valley, when the natural supplies of water such as springs, creeks and rainfall were the only supply and reticulated water was a gradual installation. The development of the distribution of water across Mitcham is discussed featuring the various forms in which is has been contained, from swamps to wetlands, tanks to troughs, fountains, dams and lakes.

## 1. INTRODUCTION

The only original boundary of the City of Mitcham is the Sturt Creek. To see the winter floodwaters roaring through Sturt Gorge behind Bellevue Heights is symbolic of an ancient power that formed our landmarks (for locations of features see map figure 1).

The aboriginal inhabitants can be remembered by the names of the three major creeks across the district. Warriparinga = Sturt Creek, meaning *a windy place by a creek* and still gully winds sweep through valley during the summer evenings; Wattiparinga, ex Viaduct Creek, meaning *plenty of water* was fed by numerous springs from beyond the railway. Through the first property donated to the SA National Trust and present day Shepherds Hill Reserve; and Wirraparinga for Brownhill Creek meaning *the scrub and creek place* no doubt because it led through the Black Forest.

Many small creeklets emulating from the foothill suburbs, some with names like Springfield and Springbank (Panorama) flow in a north-westerly direction towards these creeks. Small creeks from Springfield once fed into a swamp in the vicinity of Netherby not far from today's new wetlands.

**Figure 1:** flood in Minno Creek, Hawthorndene September (OL Wilson c 18963)

The flow of water in Brownhill Creek was so strong in the 1840s that it was proposed to build a reservoir to supply Adelaide. Another thirty years passed before it was utilized to supply Mitcham from a large 300 000 gallon (1.4 ML) iron tank nestled into the side of the hill at the top of Carrick Hill Road. Water from Brownhill Creek did however, supply the brewery where Mitcham Shopping Centre is now and was useful for meat processing across Belair Road at Mases Meats where there is the lineup of takeaway outlets today.

Wattiparinga Creek is one of the few creeks in the Adelaide Metropolitan area that retains a natural vegetation corridor from the plains to the hills.

It is hard to imagine today three-quarters of Daws Road under water for most of the winter. In 1847 Captain O'Halloran, who lived at present day "Miroma Home", wrote to the government pointing out that:

> *this accumulation of water extends from 30 to 40 yards across the whole breadth of the road leading from the eastward to St Marys Church and is something fully three feet deep in the middle.*

Council's first chairman, Ben Babbage built his mansion, in the 1870s, using water the St Marys Creek that ran through his property to mix with the local lime and stone. The quality of the water was not good and so high in salts that his castle soon collapsed. Even in the 1940s and '50s people moving into new houses at the northern end of St Marys were confronted with too much water. Their mail was left in letter boxes on Daws Road because the postman was likely to become cover in mud if he ventured far up the unmade streets.

A stream in Lower Mitcham is perhaps remembered in the name of Chasewater Street once fed by the spring utilized by drink manufacturers on the corner of Price Ave and Murray Street until the 1980s.

Most of the small creeks have been filled in and become blank laneways as through St Marys or linear reserves as through Pasadena or incorporated s landscaped gardens as in Springfield. The water that was once so troublesome is diverted into culverts and drains away from the district. Today one needs to go to one of our three main Creeks, Brownhill, Watiparinga or the Sturt to hear water singing over the pebbles or to watch the infinite ripples in ponds.

The ridge along of Sheoak Road is a significant natural feature and the water to the north drains towards Brownhill Creek and to the south into the Sturt Creek catchment.

There were once swamps around Mitcham. For instance there is the Netherby Swamp in the vicinity of the Unley High School, in fact much of the early housing of this suburb has cracking problems and it rapidly being replaced in the name of urban consolidation.

In the original plan of Colonel Light Gardens there was to be an ornamental lake in the SW corner near Mortlock Park. There was already a natural depression there that held water and it is said that it was a meeting place for the aborigines. In more recent times, old-timers remember meeting some of them on their way to town for the annual donation of blankets, and playing a game of cricket.

As the plains to the foothills were cleared, the water table rose, being natural salts with it. Mitcham's first council chairman, Benjamin Babbage, experienced the effects of this when he innocently used the water from this property, on the SE corner of South and Daws Roads to mix various forms of mortar with to build his house, or I should say castle. He struggled for five years with various mixtures before dying possibly of consumption in 1878, leaving it to his family finish. However it continued to crumble until it was finally cleared away in the 1940s.

As early as 1847 consideration was given to Adelaide being supplied with reticulated water from Brownhill Creek. By 1850, it is recorded that Brownhill Creek was flowing 10 000 gallons an hour (1.1 ML/day) during a normal March. Twenty-five years later it was only a third of that. In 1876-7 Mitcham Council lobbied the Government for a reticulated water supply as the year was very dry.

After much parliamentary discussion a design was drawn up by September 1876 and within two years a well in Ellison's Creek with a reservoir and filter beds, with a 3 inch main (75 mm) to convey the water to a 27 000 gallon (0.1 ML) tank at the southern end of Fullarton Road was installed. The contractor was Thomas Nimmo, Hydraulic Engineer, Oswald Brown and Engineer-in-charge, and W Bennett Hull. The water supplied the Mitcham area and another settlements as far north as Halifax Street, Adelaide.

The rich alluvial soils of Brownhill Creek encouraged market gardening, which was well established by 1891. That year Messrs Williams and Curtis lobbied Council to build some Manure Pits built by Alf Terry. They were used to stop the creek pollution as, instead of the wet manure, back loaded from the market, being just dumped on the side to the creek to dry and become lighter it was now contained.

## DAMS

Some dams were nothing more than depressions to hold the overflow of water from road ways, such as one which forms a reserve at present day Bedford Park draining part of Shepherds Hill Road. Others are constructions across creeks for irrigation purposes like one across the Sturt Creek in the Frank Smith Research, Coromandel Valley.

### 2.1 Brownhill Creek Bathing Reserve

Early in 1894 a draft of a lease for a Bathing reserve, near the entrance of the reserve was considered and approved by Council. A month later, the Chairman was instructed to examine plans and if he considered them satisfactory he was authorized to approve of them on behalf of the council. By 1901 rules and regulation began to be imposed with notices being posted at the dam in Brown Hill Creek and Ford at WW Winns that no bathing is allowed between sunrise and half an hour after sunset.

**Figure 2:** Brownhill Creek swimming pool weir near caravan park, 1894-1926, October 1982 (Oborn 1982).

### 2.2 Belair National Park Railway Dam

This was constructed when the railway was put through in the early 1880s. William Henry Sanders was the first Curator/Secretary of National Park and drowned on 29 December 1912. He was found drowned in the Railway Dam. Apparently Mrs J Boyle, wife of a Park employee was coming along the track from Long Gully, when she saw a person floating in the dam. She reported this, and it was found to be Mr Sanders. The story passed down is that ropes missing from the Park workshop were found with or tied to, the body. Mr Sanders was known as a good swimmer. The "open verdict:" decision of a Coroner's enquiry left no certain answer to his death. He was very well liked, by people who knew him.

### 2.3 Lowan Cres. Duck Dam, Glenalta

Excavated in the 1930s, this dam was used by Timothy Quinlan-Watson who grazed sheep in this area. He later subdivided this area naming the streets with bird names in Glenalta and Hawthorndene, with tree named streets. Ducks took up residence at the old dam and have become very possessive. Children use to bath there during the hot weather in the 1940s and '50s.

Wherever there was a pool of water, children could be seen swimming and playing. Water can keep people amused for hours, not matter their age. In spite of having not access to the sea, there has only been one public swimming pool in the district, and that was at the Sturt CAE for a few years.

**2.4 Sturt Creek Dam, Bellevue Heights**

After World War II, suburbia spread rapidly across the Adelaide Plains, pushing the safe distances of the flood plains from the creeks running from the hills. Vineyards, orchards or market gardens were subdivided into tar and cemented housing developments. Flooding became a major threat as there was no long the open paddocks to absorb the water. The South West Drainage scheme addressed the problem. The Sturt Creek was confined to a straightened concrete drain across Marion and West Torrens to the Patawalonga and an enormous dam was constructed in the Sturt Gorge during the 1960s and 1970s.

**3. LAKES**

Many of the lakes in the City of Mitcham were originally used for rural purposes, some like the one in Hannaford's orchard at Belair was filled in, but others have become ornamental lakes.

**3.1 WITTUNGA LAKE, BLACKWOOD**

Originally this lake was used to irrigate the orchard established by Edwin Ashby whose son donated this property to the Botanic Gardens in 1965 and was opened to the public in the 1970s.

**3.2 John Smith Memorial Lake, Coromandel Valley**

This "lake" was excavated by Frank Smith, after his son John died in 1957 to absorb his grief and water a walnut plantation. The water was from the nearby Sturt Creek. It is now serves as an ornamental lake and being so named in 1995 when a memorial stone was erected. Nearby a wetland is being constructed.

**3.3 Flinders University Lake, Bedford Park**

This was created when the University was built in 1965. Initially it had a difficulty of holding water.

**4. TANKS**

Tanks for house hold use is not discussed here, although there has been a tank maker in the district for many years. Rather the focus here is on tanks which old water to benefit the whole community.

**4.1 Dome Tanks, Blackwood, Panorama, Bellevue Heights, Lower Mitcham**

Few of these tanks have survived time and those that have are on private property. They were constructed for domestic use before water was laid on and a hand pump was fitted to give access to the water.
Galvanised iron tanks became more popular and are still considered a luxury rather than a necessity.

**4.1 "Reservoir", Mitcham**

One of the oldest public water installations in Mitcham has been offered for sale with land surplus to the government's requirements. The old cast iron and brick tank set in the side of Brownhill at the top of Carrick Hill Drive is a piece of forgotten heritage. Leading into the darkened depths of the tank is an old iron ladder, no longer safe. Inside, the acoustics, which could echo, are softened by meter high buffer walls across the floor which support ornate slender columns of cast iron. These support the shallow arched ceiling, molded by sheets of narrow-fluted corrugated iron.
Water flowed into this tank form 1879 from further up Brownhill Creek where one of the old cast iron fountains still stands under some trees opposite the caravan-park. Another fountain was restored by the Mitcham Rotary Club and placed in Sutton Gardens. A third fountain was installed near the institute on the edge of Mitcham Village.

What a luxury for the pioneering women, who could now simply turn a tap and have running water at their disposal, a luxury we have come to expect, and take for granted today. Mr Robert Philp was the Engineering & Water Supply Department's (EWS) serviceman for Mitcham, and the brass plate on his front gate at 67 Princes Road declared "Turncock Waterworks", fascinating school children between 1919-1950. He was born in 1883 at North Gumeracha and was relieving turncock at Norwood for several years before moving to Mitcham. The Mitcham waterworks from Brownhill Creek were gradually phased out during the 1920s when reticulated water was being brought from the Thorndon Park reservoir.

**4.2 Railway Tank, Blackwood**

This iron tank, high on a spindly stand was installed when the railway was built in 1883 to supply water for the steam trains. Blackwood was the first railway station in the hills. The water came by pipe from the National Park railway dam and down Hawthorndene Drive to Blackwood railway station's overhead tank. This was also the water supply for those who first moved to Hawthorndene in the mid-1920s as if often sprung a leak and was easily tapped.

**4. 3 EWS Tanks, Mitcham, Belair, Blackwood, Hawthorndene, Eden Hills, Clapham, Springfield**

All around the foothills the department has built large or high concrete tanks to bring a steady and reliable supply of water to the Mitcham District.

Water was laid on to Belair in 1927 but by 1940 the Belair Progress Association wrote to the E&WS in reference to water storage at Belair, pointing out that the district had been without water on three evenings during a week of hot weather. It was wartime and this problem was to continue for a number of years.

Early in the New Year of 1942 there was concern about the water supply to Blackwood,

> *increased by the fact that a large number of residences have recently been constructed at Blackwood where no provision for water tanks has been made. Whilst this can be taken as a compliment to the continuity of supply which the*

*department has been enabled to give in the past, I would respectfully suggest that it is taking a very optimistic outlook.. Anticipating the likelihood of increased development in Blackwood, this Government, during the last five years spent over 18,000 pounds in improvements to the existing supply.*

Council wrote again at the end of 1943 and again received a reply from the Commissioner of Public Works:

> *To further improve conditions in your area, an additional tank is in course of construction at Hawthorndene together with another overhead tank at Belair. Other very large storage tanks are nearing completion at Springfield... Other large tanks are in course of construction at Clapham to further assist in maintaining supplies. ...The real position is that until a new trunk main is taken from Happy Valley and linked up with the metropolitan system, no lasting improvement can be assured.*

In 1960, a Parliamentary Standing Committee on Public Works reported on the Clapham Pumping Station and Clapham-Springfield water Main. It was said that:

> *the only effective means of achieving this was by the construction of a pumping station at the Clapham Tanks, which drew their supply from the Happy Valley system, and the laying of a 24 inch* (600 mm) *main from the pumping station to Springfield to bring more water to the Springfield tanks.*

This work was duly undertaken. It took 20 years to happen, but all good things come to those who wait.

## 5. TROUGHS

Water for travelling stock was most important as a service station is for the car of today. In fact the teamsters also needed a "watering hole". Hotels serve this purpose for both as while the men were inside the horses or bullocks could take a drink from the trough outside. There were at least two such troughs in the district, one outside the Edinburgh in Mitcham Village and the other in front of the Blackwood Inn, now the Belair Hotel.

At the beginning of the summer of 1925, Mitcham Council put a request to the Commissioner of Waterworks,

> *that a supply of free water be granted to a proposed water trough at the corner of Goodwood and Daws Road, Springbank. There is no trough anywhere near this site, and it is the route for a considerable amount of horse traffic, especially from the quarries. My Council has been approached by some of the Teamsters regarding this matter, and are prepared to install a trough, providing free water can be obtained...* The request was granted.

## 6. FOUNTAINS

Fountains in Mitcham are ornamental in gardens or functional once providing drinking water on the streets.

### 6.1 Drinking Fountains, Mitcham

Three drinking fountains from the earliest reticulation system to Mitcham from Brownhill Creek have survived. One in Brownhill Creek is in a dilapidated condition, another is maintained near Mitcham Village Reserve. A third in Sutton Gardens was restored by the Mitcham Rotary Club. Another was reinstated the one that was on the corner of Welbourne Street and Princes Road.

### 6.2 Ornamental Fountain, Blackwood

In the ground of Blackwood and District Community Hospital there is a very old fountain. Background to its history is unknown but it was restored by the Lions Club in 1982.

### 6. 3 Memorial Fountains, Hawthorn

In Mitcham Memorial Gardens at Hawthorn there are two fountains, one a memorial to Dr Kyle Gault, a popular and well-known doctor around Mitcham, and another near the Scented Garden installed by the Mitcham Airforce Association.

### 6.4 Frank Collins Fountain

At the Five ways Intersection, Blackwood a fountain recorded the bravery and mate-ship of local lads....

> *In Memory of Frank Collins who sacrificed his life in vain attempt to save his friend Rodney Saint from drowning in River Sturt, Oct. 8 1927.*

Three boys were near a deep waterhole in the Sturt River when Rodney Saint went in and got into difficulty with cramp. Rodney's cry for help was heard by his sixteen year old friend, Frances Collins. Although Frank could not swim, he jumped in to help Rodney. The third by Rex Dunstan, ran to Blackwood for help. But both Rodney and Frank Collins were drowned. Mrs Collins never really recovered from her son's death and was under medical treatment for six or seven years paying for it by the other children delivering fresh milk to the doctor each morning push-bike and each week taking him a dressed fowl and fresh cream.

## 7. WETLANDS

The 1990s saw the advent of wetlands to metropolitan storm water solution. The first was at Urrbrae on Waite Research Institute land, another has been developed as part of the new Craigburn Farm subdivision and one will be part of the Frank Smith Park. Trash racks have been incorporated as part of the system and literary hundreds of tons of rubbish has been prevented from reaching the gulf waters.

### 7.1 Urrbrae

Established in 1996 to enhance the storm water quality entering the Patawalonga through the SW drainage Scheme. Local native plants are being grown around the wetlands to replicate the Black Forest that originally extended this far. The wetlands are a little to the north-west from the pre-settlement “Netherby Swamp”,

## 8. CONCLUSION

The 1970s saw great works effected by the Engineering, and Water Supply department, fluoridation was introduced, filtration planned and implemented and perhaps the most significant to the hills population, deep drainage for sewage installed

Water, its availability, storage and disposal is fundamental to life and well may be the element taken for granted the most.

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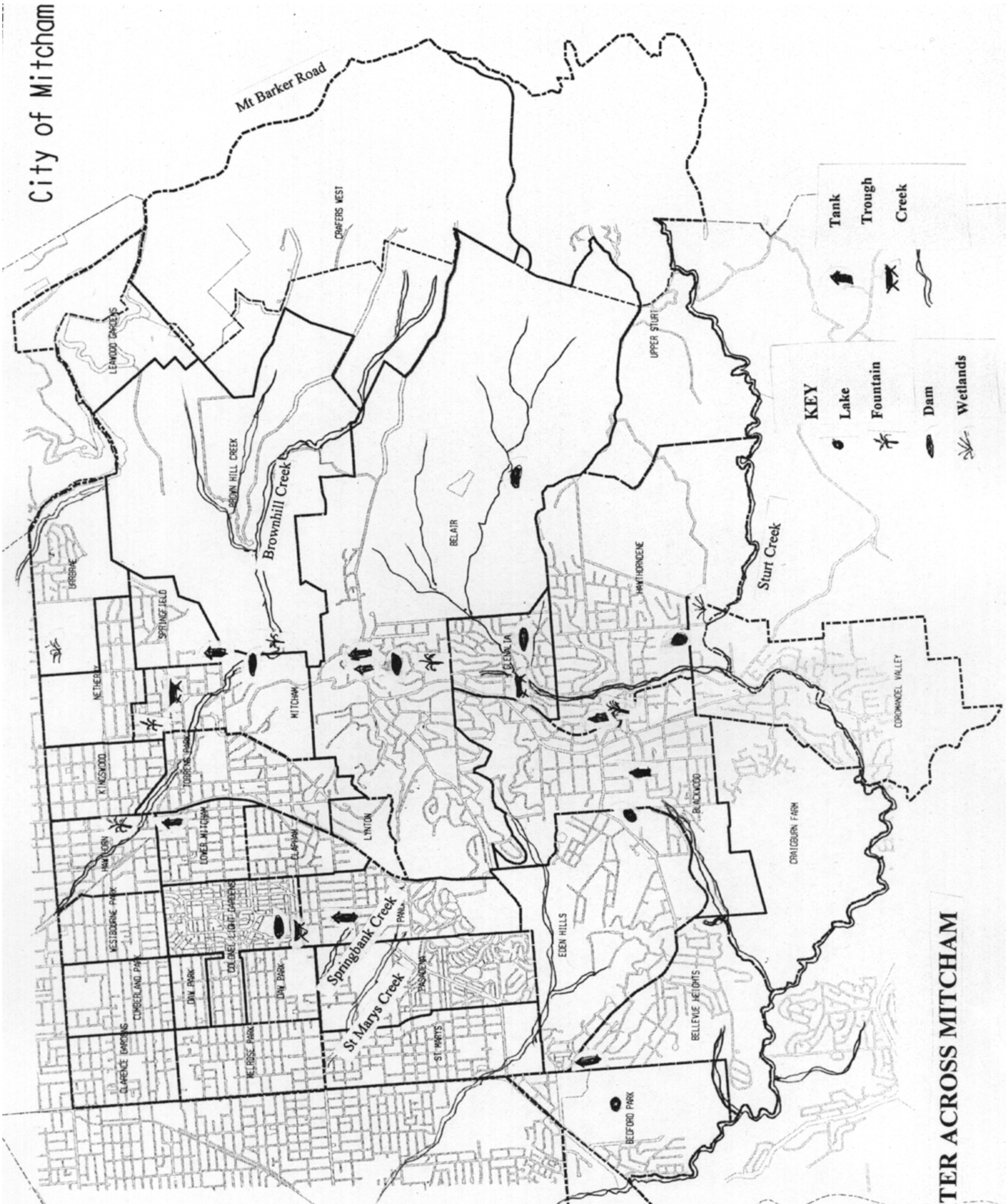


**Figure 1:** Locality map of Mitcham, South Australia showing sites discussed.

# RIVER MURRAY BARRAGES

## NATIONAL ENGINEERING

## LANDMARK

28 September 2001

The Institution of Engineers, Australia

SOUTH AUSTRALIA DIVISION

The Institution of Engineers Australia : South Australia Division
Engineering House, 11 Bagot St North Adelaide SA 5006
Telephone (08) 8267 1783 Fax (08) 8239 0932

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# RIVER MURRAY BARRAGES

## 1. INTRODUCTION

The River Murray Barrages are being recognized by Engineering Heritage Australia to commemorate the engineering works with a National Engineering Landmark as part of its Centenary of Federation program. Plaques will also be installed at the Yarrawonga weir , Blanchetown locks and Hume dam later in the year to commemorate the River Murray System. The River Murray Barrages plaques (National Engineering Landmark and information plaque) will be accepted by The Murray Darling Basin Commission and SA Water on Friday 28th September aboard the PS Murray Queen, main wharf Goolwa. The event has been included with the Hydrological Society water seminar and our special thanks is offered to Bart van der Wel of the Hydrological Society for allowing us to participate.

Our thanks to the following organizations who provided information and illustrations

SA Water
Murray Darling Basin Commission
Hydrological Society
State Department of Water Resources

Individual field notes contributors were;

Andrew Parsons
Lenore Coltheart
John Argue
Ross Foster
Nigel Ridgway
Bart van der Wel

## Plaquing ceremony order 5.00 pm

| | |
|---|---|
| Introduction | Conference Chairman , Bart van der Wel |
| Plaquing program | Engineering Heritage Branch Chairman , SA Division Nigel Ridgway |
| Plaque unveiling | National Vice President Institution of Engineers, Peter Koukourou |
| Acceptance | CEO Murray Darling Basin Commission, Dr Roy Green |

## Existing plaques

There are two plaques already installed at the Goolwa barrage including a Murray Darling Basin Commission plaque of 1998 which commemorates the barrage and lockworkers reunion. There is also a plaque commemorating the construction in 1940. See the appendix for pictures of these plaque texts.

# 2. NAME, OWNERSHIP AND PLAQUE TEXT

| | |
|---|---|
| Current Name….. | River Murray Barrages. |
| Current Owner…. | Murray-Darling Basin Commission<br>Gas Industry House<br>7 Moore Street<br>Civic,<br>Canberra, ACT |
| Local Aboriginal Community… | Ngarrindjeri |
| Location …… | Near the mouth of the River Murray in South Australia.. |
| Map ……. | The barrages are shown on the 1:50,000 SA Lands Dept Maps entitled “Goolwa 6626-1” and “Narrung 6726-4”. |
| Boundary …….. | There are five separate boundaries (for National Estate listing), each boundary corresponding to the extremities of the five barrages. |
| Local Government …… | District Council of Alexandrina (Goolwa and Mundoo Barrages).<br><br>District Council of The Coorong (Boundary Creek, Ewe Island and Tauwitchere Barrages) |
| Register of the National Estate… | The River Murray Barrages were successfully nominated for listing on the Register of the National Estate by the owner (SA Water) in June, 1998 |
| Access to the site…… | A popular summer recreational area and information kiosk with an estimated 100,000 visitors annually, is located adjacent to the main barrage (Goolwa Barrage) which is open to the public. |
| Future care and maintenance…. | The Barrages are integral components of the River Murray locks and weirs system operated by the Murray-Darling Basin Commission. The Barrage structures are held in trust by the State of South Australia for the Commission and are managed and operated by SA Water (formerly Engineering and Water Supply Department) on behalf of the Government of South Australia. |
| Name of Sponsor….. | SA Water and Murray Darling Basin Commission |

NEL plaque…… The plaques will be set on a specially-built cairn located adjacent to the right abutment of the Goolwa Barrage, at the eastern extremity of the picnic area.

The information plaque text is as follows;

**RIVER MURRAY BARRAGES**

The barrages were designed and constructed by the Engineering and Water Supply Department of South Australia between 1935 and 1940, and funded by the Governments of the Commonwealth of Australia and the states of New South Wales, Victoria and South Australia under the River Murray Waters Agreement. Their type and scale are unique in Australia. They maintain fresh water in Lakes Alexandrina and Albert and stabilize water levels to allow irrigation of adjacent land and upstream lands whilst river floods pass through the concrete sluice and gate sections. A lock in the Goolwa barrage permits the passage of large vessels, and a lock in the Tauwitchere Island barrage caters for small boats. Without the barrages, the growth of Adelaide and the supply of water from the lower River to the lower South-East of the state would not have been feasible.

Dedicated by The Institution of Engineers, Australia,
Murray-Darling Basin Commission and
South Australian Water Corporation 2001

# 2. OVERVIEW OF THE NOMINATION

## 2.1 NAME OF WORK AND LOCATION

The **River Murray Barrages** are located approximately 75km SSE of Adelaide near the mouth of the River Murray . There are five separate barrages. One barrage is located across the main channel just upstream of the mouth of the River Murray near the historic river town of Goolwa, the other four are located across the shallow waterways and channels that run between Lake Alexandrina and the northern end of the Coorong.

## 2.2 BACKGROUND, CONSTRUCTION AND OPERATION

From the earliest days of European settlement along the lower reaches of the River Murray there were strong representations from landowners for the construction of barrages, either across the river near Wellington, to keep the lower reaches of the river fresh, or near the Murray Mouth which would also keep Lakes Alexandrina and Albert fresh. These representations led to several proposals in the 1890s.

The River Murray Commission was created in 1915 to represent the interests of the three states through which the River Murray flowed and the Commonwealth in the regulation and apportionment of the waters of the River Murray. Early projects concentrated on establishing permanent navigation of the river and stabilization of river levels for irrigation. It was not until 1931 that their attention turned to the river mouth when the lock and weir program was discontinued due to the rapid decline in river navigation.

The design and construction of the barrages was undertaken by the then Engineering and Water Supply Department using its own resources and construction equipment previously used on the locks and weirs construction. In accordance with the River Murray Waters

Agreement of 1915, costs were shared equally by the Governments of Victoria, New South Wales, South Australia and the Commonwealth.

Work on the barrages commenced in 1935 and was completed in 1940. At the completion of construction the total cost was 750,000 pounds. Approximately half of the cost was absorbed by Goolwa Barrage. The Barrages were first put to the test during the 1944-45 drought when they proved that they were capable of preventing the ingress of the sea during periods of low river and maintaining the freshness of Lakes Alexandrina and Albert. It also proved that Adelaide could be supplied from the River Murray if desired.

Before the construction of the barrages, tidal effects and intrusion of sea water during periods of low river flow were felt up to 250 km upstream of the mouth. Without the barrages, supply of water to Adelaide and the Lower South-East of the state using pipelines from the lower reaches of the River would not have been feasible. In an average year the River Murray provides approximately 40% of Adelaide's water and in dry years this can go as high as 90%. Over 14,000 hectares is under irrigation between the barrages and Lock 1 at Blanchetown.

## 2.3 PRESENT PHYSICAL CONDITION

The Barrages at the mouth of the River Murray are integral components of the system of barrages, locks and weirs used to regulate flow in the waterway over a river distance of nearly 1700 km. The continued maintenance of the Barrages is one of the main responsibilities of the Regional Office of SA Water, on behalf of the Commission, located in Murray Bridge, SA.

## 2.4 HISTORICAL BIOGRAPHIES

The designs for the Barrages were prepared under the supervision of Mr. John Henry Osborn Eaton, Engineer-in Chief of the Engineering and Water Supply Department, and his successor, Mr. Hughes Thomas Moffit Angwin. Mr. Elwyn Ross Lawrie was the Engineer for Construction and the Resident Engineer was Mr. H.G. Oliver.

John Henry Osborn Eaton, who was born at Goolwa in 1869, joined the Engineer-in-Chief's Department in 1884 and rose through the ranks to be appointed the first Engineer-in Chief of the Engineering and Water Supply Department when it was formed in 1929. (For the following 65 years the Engineering and Water Supply Department played an important role in the development of South Australia. In 1995 it was replaced by the South Australian Water Corporation.) In 1918 he was appointed a Member of the River Murray Commission. Eaton was the Chairman of the Institution of Engineers SA Division in 1922. Note Eaton designed the Barrossa Dam "whispering wall".

Hughes Angwin joined the Engineer in Chiefs department in 1913 and worked on the Murray locks construction. He became Assistant construction Engineer in 1924 and Engineer for Water Supply in 1929 . He was eventually promoted to Engineer in Chief succeeding Eaton in 1936 until 1949 . Angwin was also a Deputy Commissioner of the River Murray Commission from 1946.

Elwyn Lawrie worked on irrigation works early in his career and became Chief Constructing Engineer of the Irrigation and Drainage Commission in 1927. He was then appointed Engineer for Construction in 1935 and Engineer for Water Supply in 1947. Lawrie was Chairman of the SA Division , Institution of Engineers in 1954.

## 2.5 TECHNICAL SUMMARY (AS CONSTRUCTED)

| | |
|---|---|
| Dam Construction.... | Goolwa Barrage is constructed of concrete; each of the other barrages is an earth embankment with concrete sluices. The sluice sections comprise a footing slab supporting closely spaced piers. Between the piers either hinged radial gates or removable stoplogs are installed to control water level and trafficable deck units span between the piers to allow the passage of vehicles (for operational reasons only, the barrages are not public roadways). A lock is incorporated into the Goolwa Barrage to permit passage of large vessels and a smaller lock is located in Ewe Island for small boats. |
| Purpose …… | The purpose of the barrages is to maintain Lakes Alexandrina and Albert as fresh water lakes and to stabilize the lake levels to allow irrigation of adjacent land. The barrages are designed to pass river floods through the concrete sluice sections without raising the lake levels but prevent the ingress of sea water. |
| Height …… | Goolwa 5.8 m above channel bed<br>Other Barrages 1.5 m above channel bed |

| | | |
|---|---|---|
| Length …… | Goolwa | 632 m |
| | Mundoo | 792 m |
| | Boundary Creek | 243 m |
| | Ewe Island | 2,271 m |
| | Tauwitchere | 3,658 m |

| | |
|---|---|
| Lake Volume …… | The volume of fresh water in Lakes Alexandrina and Albert controlled by the barrages is approximately 2 million megalitres. |

## 2.6 MODIFICATIONS

Over the years since first constructed, changes have been made to components of the barrages but the original concrete work has remained relatively intact and in generally good condition. The main changes that have been made are:

- Mechanisation of the lock gates in Goolwa Barrage.
- Replacement of timber stop logs with precast concrete stop logs
- Replacement of the original steel radial gates with new gates of similar design
- Replacement of the original timber decking with precast concrete deck units and (where public access is permitted at Goolwa Barrage) open grid walkways and handrails.

# 3. STATEMENTS OF ENGINEERING HERITAGE SIGNIFICANCE

The River Murray Barrages' claim for registration as a National Engineering Landmark is primarily due to its uniqueness in Australia in terms of the type and scale of the works. The Barrages are unmatched by any other similar control structures elsewhere in Australia. Without these structures the growth of Adelaide to the metropolis of one million people that it is today would not have been possible.

**CRITERION A3** *Importance in exhibiting unusual richness or diversity of landscapes or cultural features.*

The construction of the Barrages had a major impact on the biota and landscape in Lake Alexandrina due to the maintenance of a pool of fresh water and regulation of river flows in the lower reaches of the River Murray. The leaching of salt by the fresh water brought about a change in the vegetation around the shoreline (Faull, 1981). The Barrages are located at the northern end of the Coorong and they have had and will continue to have an impact on this environmentally significant and fragile area through the reduction and regulation of river flows into the Coorong

**CRITERION A4** *Importance for association with landmark events, developments or stages in Australian history or in the history of a state, region or community.*

The Barrages were designed to protect the Lower Murray against salinity. In times of low flow salt water entered the River Murray at its mouth and infiltrated a considerable distance upstream. The barrages were therefore associated with development of the Lower Murray by ensuring river water in this region remained fresh and flows regulated at all times.

Apart from the benefits provided, the Barrages are associated with the early days of the then River Murray Commission (now Murray Darling Basin Commission) which comprised three states, South Australia, Victoria, NSW and the Federal Government. The establishment of the River Murray Commission is probably a landmark event in the development of the Murray-Darling Basin which is one of the largest drainage basins in the world.

The Goolwa and Mundoo Barrages abut Hindmarsh Island which is associated with perhaps the most significant indigenous heritage issue in Australia's history - the building of a road bridge to Hindmarsh Island across the River Murray at Goolwa. This issue and the ruling of the High Court in March 1998 (that the bridge could go ahead) is of considerable Constitutional import, with implications for the relationship between Federal and State laws, for the status of indigenous people, the process of reconciliation and Australia's standing in the international human rights forums.

**CRITERION B2** *Importance in demonstrating a distinctive way of life, land use, function, or design no longer practiced, in danger of being lost, or of exceptional interest.*

The River Murray Barrages are the only barrages of this type and scale in Australia. The system comprises 5 barrages, Goolwa, Mundoo, Boundary Creek, Ewe Island and Tauwitchere. Total length of all barrages is 7.6 km with the longest Tauwitchere being 3.6 km.

It is unlikely that structures of this scale will ever be repeated in Australia.

**CRITERION E1** *Importance for a community for aesthetic characteristics held in high esteem or otherwise valued by the community.*

The barrages are set in a landscape that is unique in Australia, being estuarine near the river mouth and adjacent to the Coorong. The structures being of low height, do not make a significant visual impact the landscape. Because of the important function that the barrages perform (separation of sea water from fresh water and maintenance of lake level) the barrages are highly valued by the community.

The barrages are located in a popular summer recreational area for the state and Goolwa Barrage is open to the public. An information kiosk is located at Goolwa Barrage.

**CRITERION G1** *Importance as a place highly valued by a community for reasons of symbolic, cultural or social associations.*

The barrages have created a permanent pool of fresh water (Lake Alexandrina and Lake Albert) which is in an important animal habitat and water resource highly valued by the community and state.

In support of their battle on the Hindmarsh Bridge issue, the local Aboriginal people claim and have provided evidence that Kurranderk (Kurranderk is the Ngarrindjeri name for Hindmarsh Island) and the river, including where the barrages are located, has ritual and symbolic significance for women. That this is highly valued is shown by the intense and determined struggle that is being maintained on the issue.

# 4. REFERENCES

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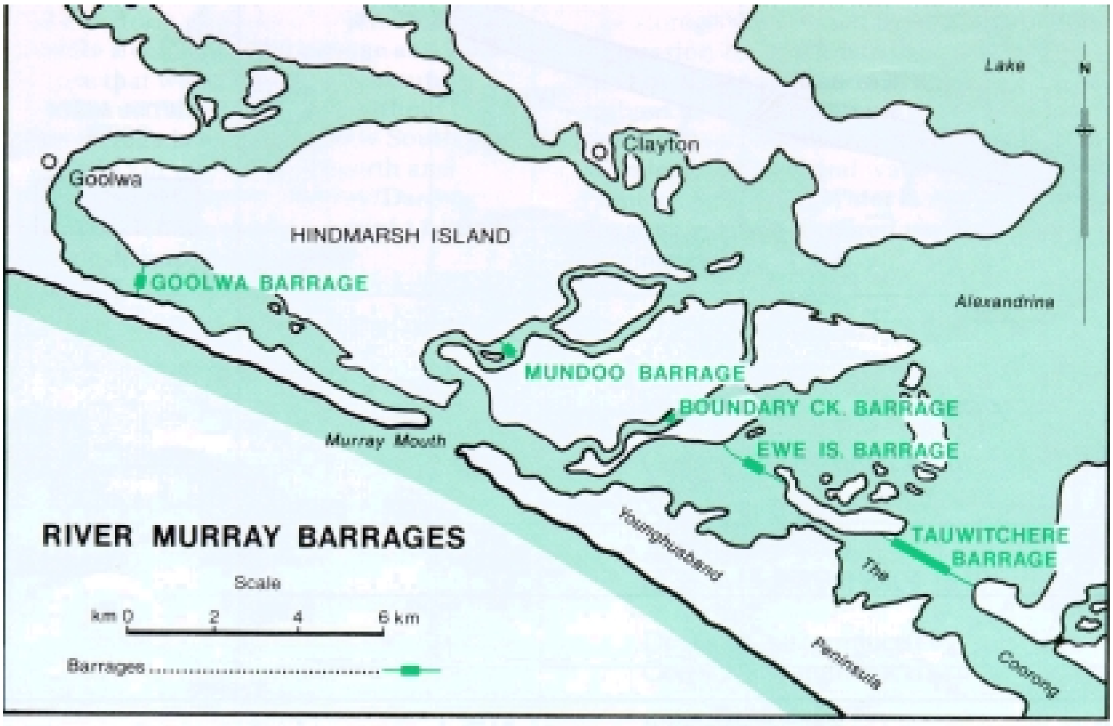
# 5. APPENDIX

1. Murray Darling Basin plaque existing
2. EWS plaque existing
3. Barrage map


1. River Murray Barrages plaque

2. Murray Darling Basin plaque




3. Barrage map

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